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MATURITY STUDIES WITH SWEET CHERRIES[1]

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INTRODUCTION

Sweet cherry production is an important branch of the fruit industry in the Okanagan Valley of British Columbia. The Bing and Lambert varieties constitute about two-thirds of the crop which now totals about three million pounds a year. The sweet cherry is a high quality fruit, but must be picked eating ripe in order to be most attractive to both eye and palate. Cherries do not improve in quality after picking. In commercial practice, however, they are often picked in a somewhat immature condition, which results in poor quality.

One of the main causes of premature picking of cherries in the past is the market demand for early shipments. Cherries are required early in the season for inclusion in mixed cars and to meet competition from imported produce. The high prices sometimes secured for the first shipments of cherries to reach the market have encouraged growers in early maturing areas such as the Oliver district to pick their fruit before it reached satisfactory maturity. However, the unified marketing control now in operation in British Columbia promises to check the shipment of obviously immature cherries.

The loss from splitting is a serious consideration with cherry growers. Nearly every year there is some rain at cherry picking time, and if the rainy period is long, or if humid atmospheric conditions follow the rain, a large percentage of the fruit may split. The more mature a cherry is, the more susceptible it is to splitting. When serious splitting occurs, the grower suffers a direct loss in tonnage. Furthermore, the presence of split cherries along with sound fruit in the harvested crop increases the cost of packing and the danger of loss from spoilage. Unless the protective sprays against rain splitting now being investigated by Foster (1) and Verner (3), come into practical use, fear of loss from splitting will continue to frighten some growers into picking a portion of their crop before maturity. Fortunately cherries picked in an immature condition are suitable for processing. Accordingly, development of the glaced cherry industry in the Okanagan Valley makes it possible to harvest a portion of the crop early for processing.

The cherries on heavily laden and sick trees mature more slowly than those on vigorous trees carrying a medium or light crop. Failure to appreciate this fact has often resulted in harvesting fruit at varying stages

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of maturity. Furthermore, the crop on trees which have been weakened by winter injury or adverse soil conditions sometimes fails to develop high quality no matter how long harvesting is delayed.

Lack of a simple and reliable maturity test has also contributed to harvesting of cherries at unsatisfactory stages of maturity. Accordingly, a project was started at the Summerland Experimental Station in 1935 to study the changes in cherries prior to maturity, and to devise some practical index whereby maturity might be determined. These tests have been carried out with a number of varieties, but the work has been concentrated mainly on Bing and Lambert, which are the two most important dessert cherries grown in British Columbia.

The foregoing discussion of factors responsible for immature picking of cherries in the past reveals that the task of standardizing the maturity at which cherries are picked is by no means a simple one. Any practical guide for picking cherries must be used with full realization of the many qualifying factors that are involved.

PROCEDURE AND RESULTS

Picking date experiments have been conducted each year with trees located on the orchards of the Summerland Experimental Station. In addition, large numbers of commercial samples of fruit from packing houses have been collected and examined, records being made of such factors as skin colour, soluble solids content, quality and storage behaviour.

A small pocket-model Zeiss refractometer with a range of 0 to 30% has been used in these studies to determine percentage soluble solids in the juice. Along with the refractometer is supplied a nut-cracker-shaped squeezer for expressing the juice. The juice from 10 cherries can easily be obtained in 2 minutes. After stirring this juice, a drop or so is quickly transferred to the refractometer and a reading made. The test is simple, rapid, and reduces the personal factor to a minimum. Parallel chemical analyses have revealed that most of the soluble solids indicated by the refractometer are sugars.

Effect of Maturity on Skin Colour, Soluble Solids, and Weight

To study the changes which take place in cherries during the two weeks prior to harvest, systematic pickings were made in 1936 and 1938 with Bing and Lambert. The fruit was harvested from heavy crop trees on picking dates spaced 5 days apart. Representative samples were picked from 4 sectors of the tree to give a composite sample. In the laboratory, the weight of 100 representative fruits was determined, a Zeiss reading made, and appearance of the fruit noted. The 1938 data are presented in Table 1.

From the data presented in Table 1 it is apparent that a very striking increase in fruit size took place with both varieties as maturity progressed. On the first date of picking with both varieties, the fruit was in perfect condition for processing into candied and maraschino cherries. From this time on until 15 days later when the fruit had reached optimum harvesting maturity, an increase in weight of 37% occurred in both varieties. This

TABLE 1.—EFFECT OF DATE OF PICKING ON SKIN COLOUR, SOLUBLE SOLIDS, WEIGHT, AND QUALITY OF CHERRIES—1938

Variety	Picking date	Skin colour	Quality	Soluble solids	Weight of 100 cherries	Increase over weight at start
	1938			%	gms.	%
Bing	June 23	Light red	Poor	14.2	545	—
	June 28	Light red	Poor	15.3	613	12.5
	July 2	Light red to dark red	Fair	17.5	695	27.5
	*July 7	Dark red	Good	17.9	747	37.0
	July 12	Black	Good	19.1	731	34.0
Lambert	July 1	Light red	Poor	12.9	463.5	—
	July 6	Light red	Poor	12.3	537.5	16.0
	July 11	Light red to dark red	Fair	14.0	598.0	29.0
	*July 16	Dark red	Good	14.9	624.0	37.0
	July 16	Dark red	Good	15.9	616.0	33.0

* Optimum maturity.

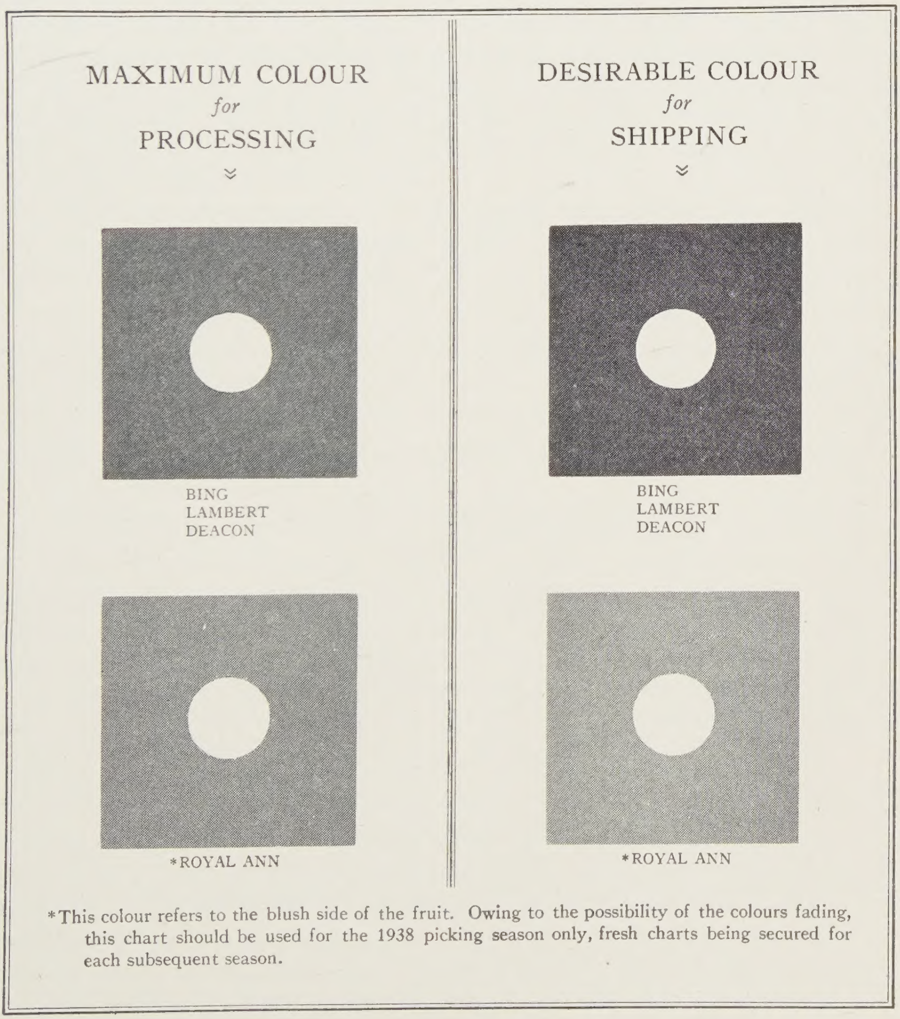

Figure 1. Facsimile of Colour Chart Maturity Test for Cherries.

amounts to 2.47% per day, a figure somewhat higher than the 1.3% increase reported by Hartman (2) for the Lambert variety. In the 5 days which followed the date of optimum harvesting maturity, the fruit actually lost slightly in weight. This loss of weight was probably due to desiccation associated with overmaturity.

It is interesting to note that the percentage of soluble solids for Bing increased from 14.2 to 17.9 between the first picking and optimum maturity, while for Lambert it increased in a similar period from 12.9 to 15.9%. Samples of Bing and Lambert from other sources attained a soluble solids content of 20 and 18% respectively at optimum picking maturity. The comparatively low soluble solids content attained by both varieties in the above picking date experiment was probably due to the exceptionally heavy crop carried by the trees.

At optimum maturity with both varieties, the skin and flesh colour was a dark red shade, while undermature fruit showed various shades of light red. Overmature fruit of the last picking was almost black in colour, and had lost the lustre of fruit at its prime. Paintings were made to record the colours observed, and from these a simple colour chart was prepared to serve as a practical maturity test to be used by the grower in the orchard. A facsimile of this chart is shown in Figure 1. At desirable maturity for processing, dark varieties of cherries such as Bing, Lambert and Deacon had a light "tomato" red skin colour. About two weeks longer on the tree was necessary to develop the rich dark red which indicated satisfactory maturity for fresh shipments.

Flesh colour changes closely paralleled skin colour changes, flesh colour of immature fruit being pink or light red, and of mature fruit dark red. The darkening occurred first near the pit. This change in flesh colour near the pit was a fairly reliable index of desirable maturity for fresh shipment.

Maturity of Samples Secured from Commercial Packing Houses

In order to secure information on which to base a simple maturity test for cherries, it is desirable to examine many samples of cherries secured from different districts. In addition, it is important that such work extend over a period of several years, because seasonal conditions vary considerably from year to year.

Accordingly, samples of Bing and Lambert cherries were collected from packing houses in the Kelowna, Summerland, Penticton, Oliver, and Osoyoos districts during the past four years. These samples were selected at random and thus represented a composite picture of the fruit as it arrived at the packing houses before being graded for shipping or processing.

Marked variation in maturity was found between samples and also within samples. Evidence regarding the maturity of 97 samples of Bing and 42 samples of Lambert collected in 1938 is presented in Table 2.

TABLE 2.—MATURITY OF COMMERCIAL SAMPLES OF CHERRIES

Maturity as indicated by skin colour	Percentage samples in each maturity group	
	Bing	Lambert
	%	%
Uniformly mature	35.1	37.2
Uniformly immature	21.6	31.4
Variable maturity in each sample	43.3	31.4

The data presented in Table 2 show that only slightly more than one-third of the samples of both varieties were both uniform and of desirable maturity when delivered at the packing houses. A slightly smaller number were uniform but immature, while 43% of the Bings and 31% of the Lamberts were variable in maturity. By variability in maturity is meant that both mature and immature fruits were found in the same sample.

Correlation Between Skin Colour and Soluble Solids

In order to ascertain how closely skin colour is correlated with soluble solids content in the juice, the following data were assembled from the 150 samples of fruit studied in 1938.

TABLE 3.—CORRELATION BETWEEN SKIN COLOUR AND SOLUBLE SOLIDS CONTENT OF CHERRIES

Variety	Soluble solids content of cherries in skin colour grades		
	Dark red	Medium red	Light red
	%	%	%
Bing	20.3	18.4	17.7
Lambert	17.7	17.9	16.7

The data embodied in Table 3 show that with Bing there was a good correlation between skin colour and soluble solids content. However, with Lamberts the correlation was not so consistent; in fact, in a number of cases, skin colour gave very little indication of the soluble solids content. In 1939 this same observation was made with the Lambert variety. Dark coloured cherries, usually rather small, and probably from overloaded or sick trees, were often found in a fully mature condition, and yet with a low soluble solids content and watery texture. On the other hand, firm cherries of fairly high sugar content were sometimes found with only a medium red skin colour.

Correlation Between Soluble Solids and Quality

The following data were secured from fruit collected from commercial packing houses in 1938. On the day of collection, each sample was tested with the Zeiss refractometer, notes made on quality and skin colour, and the sample put aside for 7 to 10 days at 65° F. and 80% relative humidity to observe its ability to remain in good condition after picking. The

fruit was classified into three quality grades: good, fair, and poor. "Good" fruit was mature and of high quality. "Fair" fruit was passable, but usually a few days under optimum maturity. "Poor" fruit was immature, or else small, watery, poorly grown fruit from sick trees. After a 10-day storage period, the fruit was again classified into the three quality grades, and by referring to the lot numbers of the samples, their soluble solids reading at picking time could be ascertained. This permitted comparison of storage quality of cherries with their soluble solids content at picking. The data are presented in Table 4.

Table 4.—Correlation between soluble solids content and quality of cherries at picking and after storage at 65° F.

Classification of samples at:	Soluble solids content of samples in the following quality grades		
	Good	Fair	Poor
	%	%	%
Bing			
Picking time	20.1	18.5	17.6
After 10 days' storage	20.25	19.2	17.6
Lambert			
Picking time	18.2	17.3	16.4
After 10 days' storage	18.6	17.5	16.6

The above data indicate that there was a good correlation between soluble solids content and quality, both at picking time and after storage. These data make it clear that the cherry samples which were classified as either good, fair or poor at picking time, largely fell into the same categories after a short storage period at 65° F. The most mature samples kept firm and bright, while the immature samples shrivelled, remained light red in appearance, and were poor in quality. The results of storage tests conducted in other years substantiate the contention that cherries picked when the skin is dark red in colour keep better than those picked in an immature condition.

Effect of Seasonal Conditions on Soluble Solids

Information concerning the influence of seasonal conditions on the soluble solids content of Bing and Lambert cherries is presented in Table 5.

Table 5.—Effect of seasonal conditions on soluble solids content of Bing and Lambert cherries

Year	Soluble solids content at optimum picking maturity	
	Bing	Lambert
	%	%
1935	20.5	—
1936	19.0	17.0
1938	19.5	18.0
1939	—	16.7

It will be obesrved that the average soluble solids content of cherries picked at optimum shipping maturity varied somewhat from year to year. Furthermore, it should be pointed out that occasional samples of cherries, especially Lamberts, were found to be fully mature in other respects although they contained considerably less soluble solids than the figures shown in Table 5.

Nevertheless the data secured during the past four years indicate that as a general rule a soluble solids content of about 19% for Bings and 17% for Lamberts is necessary to ensure good dessert quality.

SUMMARY

The importance of harvesting cherries at the proper stage of maturity for fresh fruit shipment is pointed out. Reasons why cherries have been picked in an immature condition in the past are outlined. Harvesting and storage experiments designed to ascertain simple and reliable maturity indices are described and results secured over a 4-year period are presented. The principal findings may be briefly stated.

1. In the 15 days preceding optimum picking maturity of Bing and Lambert cherries, there was a change in skin colour from light red to dark red, an increase in soluble solids of 3%, and an increase in weight of 37%.

2. Samples of cherries picked from commercial packing houses varied greatly in maturity.

3. There was a close correlation between soluble solids content and quality. As a general rule a minimum soluble solids content of 19% for Bings and 17% for Lamberts was necessary to ensure good dessert quality.

4. Amount of crop carried, vitality of tree, and seasonal conditions each influenced soluble solids content at optimum picking maturity.

5. Development of dark red skin colour in Bing and Lambert cherries was a reliable index of optimum picking maturity, even though fruit at optimum maturity did not always have a high soluble solids content. A colour chart showing desirable colour stages at which to pick Bing, Lambert, Deacon, and Royal Ann cherries for fresh shipment and for processing was prepared.

6. Skin colour and soluble solids content were closely correlated with the Bing variety, but the correlation was not always consistent with the Lambert variety.

7. Fruit picked at optimum maturity for quality kept firm and bright in common storage, whereas fruit picked in an immature condition tended to shrivel.

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PASTURE STUDIES XVII.

THE RELATIVE ABILITY OF STEERS AND RABBITS TO DIGEST PASTURE HERBAGE[1]

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Digestibility studies with cattle usually involve large expenditures of labour, time and money. In addition the amount of feed required is large and becomes a limiting factor in certain pasture investigations. Thus a strict limitation is placed upon the number of trials with large animals that can be completed in a set time, and also upon the reliability and precision that may be attained in experimental work.

The use of a "pilot" animal immediately suggests itself. The rabbit on account of its ability to subsist on pasture herbage, its low feed requirement and ease of handling would seem to fulfil, in these respects at least, the requirements of a satisfactory pilot animal in some phases of the study of the nutritive value of pasture herbage. However, before the rabbit can be used as a pilot for steers, information is required as to the relative abilities of the two species to digest similar diets.

The only available records in the literature comparing the digestibilities of rations by steers and rabbits appear to be those of Weiske (5, 6) and von Kneiriem (4). While not affording a valid comparison of the two species, since the diets fed were not identical, these works suggest that the digestive abilities of the rabbit and ruminant are of somewhat the same order.

Marked differences in growth promoting properties, and in digestibility by rabbits between different samples of pasture herbage have been demonstrated in studies at Macdonald College. The extent to which these findings may be applicable to steers awaits information bearing on the comparative behaviour of rabbits and steers fed exclusively on such diets. The hereinafter reported data have resulted from studies of this problem.

Comparisons involving 4 clippings of pasture grass have been completed, the first in 1937 and the remaining 3 in the fall of 1938. The general plan of this study has been to conduct digestion trials with a group of steers and a group of rabbits fed identical diets of dried ground mixed herbage clippings.

For all trials the herbage used was obtained from the College campus and was composed largely of Kentucky blue grass, red top and wild white clover. In all, four trials were carried out; trial A in 1937 and trials B, C, and D in 1938. While similar in many respects, the trials of the two years differ somewhat and lend themselves most suitably to separate discussion.

TRIAL A. SEPT.-OCT., 1937

The herbage for Trial A was a composite of weekly clippings collected during the summers of 1936 and 1937. The 1936 clippings were artificially dried while those of the 1937 season represented both artificially and sun

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dried herbage. The dried grass was ground in a hammer mill to pass a 5/16 inch screen. The clippings were composited and mixed thoroughly in a power-driven feed mixer. The completed mix was then divided for feeding to steers and rabbits.

Four steers and 5 rabbits were used in the tests. With each species the trials involved a 7-day preliminary and 14-day collection period. The preliminary period was started only after the animals had become thoroughly accustomed to the diet. This allowed for a constant feed intake during the 7-day preliminary period. The steer allowance was set at 20 pounds of air dry feed daily, none of which was refused or wasted. The rabbit allowance was 130 grams daily with an average recorded consumption of 125.4 grams per rabbit (standard deviation ± 3.11 grams).

The steer faeces were collected by means of a special harness and sack originally designed by Garrigus and Rusk (3). These were emptied twice daily. A 1/50 aliquot of each collection was acidified with acid alcohol (1 cc. of conc. H_2SO_4 to 99 cc. of ethyl alcohol) and dried to constant weight at 110° C. The dried aliquots were composited for each steer for chemical analyses.

Routine chemical analyses were carried out on the dried feed and faeces according to standard A.O.A.C. methods. Lignin and cellulose were determined by procedures recommended by Crampton and Maynard (1).

The cellulose procedure was used without modification, but the lignin determination was modified by autoclaving the samples (15 minutes at 15 lb.) before the digestion in pepsin-hydrochloric acid.

Results and Discussion

The coefficients of apparent digestibility found for steers and for rabbits are given in Table 1. It will be noted that the digestibility coefficients for rabbits are lower for every nutrient than those determined for steers. It is evident, however, that the 5 rabbits were on the whole about as uniform in their response as were the 4 steers. This means that no greater numbers of rabbits are needed than of steers for the determination of equally reliable average digestion coefficients. The difference in level of digestibility between the two species of course does not preclude the usefulness of rabbits as pilots for steers, providing the two species maintain the same relative difference on different diets. To obtain data on this latter problem was one of the objects of the studies conducted during 1938, and described below as trials B, C, and D.

TRIALS B, C, AND D. SEPT.-NOV., 1938

For these tests the herbage from an area of the College campus, clipped periodically during the summer of 1938, was divided into three lots. Clippings obtained during May were fed in trial B; those collected during July and early August were fed in trial C; while those of the remainder of the season became the diet in test D. All clippings except those taken in September were sun dried. The September clippings were dried in a forced draught hot air drier. The materials were prepared for feeding as described for trial A.

TABLE 1.—APPARENT DIGESTIBILITY COEFFICIENTS OBTAINED WITH STEERS AND RABBITS FED IDENTICAL DIETS OF DRIED PASTURE HERBAGE CLIPPINGS

TRIAL A

	Dry matter	Organic matter	Crude Protein	Ether Extract	Crude fibre	N-free extract	Total* carbohydrates	Lignin	Cellulose	Other† carbohydrates
Steer average (4)	64	67	75	30	66	67	67	34	68	92
S. D.	±1.7	±1.8	±1.2	±2.0	±5.5	±1.5	±2.3	±2.5	±2.7	±1.6
Rabbit average (5)	45	46	65	19	24	45	39	18	33	62
S.D.	±0.8	±0.9	±1.1	±2.9	±2.4	±1.9	±1.2	±2.1	±3.0	±1.5

* Total carbohydrates = nitrogen-free extract + crude fibre.
† Other carbohydrates = dry matter − (ash + protein + ether extract + lignin + cellulose).

Four steers and 6 rabbits were used in these digestibility trials, the same animals being used for each of the 3 tests. The steers were allowed an intake of 20 pounds air dry feed per day in each of the 3 trials. No feed was wasted or refused at any time except by one steer (No. 3) which during the first days of trial D failed to consume his allowance. His feed was reduced for a brief period and then increased to a level somewhat lower than the original one. The steer completed the last 9 days of the test with a uniform feed intake. The same steer on the tenth day of the collection period of trial C consumed an unknown quantity of hay and was removed from that test on the morning of that day; results for this steer were calculated on the basis of the shortened period.

The rabbit allowance as before was 130 grams daily, with an average recorded intake of 124.1 grams (standard deviation ±4.37 grams).

The method of collecting the faeces was the same as that outlined for trial A, as were also the chemical procedures excepting for minor changes in technique, such as the use of diatomaceous earth in filtering crude fibre, and acid hardened filter paper to replace bolting silk for filtering in the lignin.

Statistical Analysis of Data

The coefficients of apparent digestibility obtained from the 3 digestion trials were analysed by the method of variance and covariance (Fisher, 2).

Since correlation studies can be performed only with paired observations, rabbits No. 31, 33, 34, and 36 were chosen at random from the 6 fed and paired with steers 1, 2, 3, and 4 respectively. The analyses of variance and covariance were based on these 4 pairs of animals. The standard error used in connection with coefficients of digestibility was calculated from the residual variance remaining after removal of that due to diets.

Results and Discussion

The mean coefficients of apparent digestibility for each food fraction together with the standard deviations are given in Table 2.

As in trial A it will be noted that the digestibility coefficients for rabbits are lower for every nutrient than those determined for steers. If the figure for dry matter can be taken as an indication of the overall digest-

TABLE 2.—APPARENT DIGESTIBILITY COEFFICIENTS OBTAINED WITH STEERS AND RABBITS FED IDENTICAL DIETS OF DRIED PASTURE HERBAGE CLIPPINGS

TRIALS B, C, AND D

Trial	Animals	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract	Total* carbohydrates	Lignin	Cellulose	Other† carbohydrates
B	Average for 4 steers	70	74	77	34	77	74	75	15	79	97
	Average for 6 rabbits	51	52	70	35	24	53	44	6	28	72
C	Average for 4 steers	62	66	72	7	65	67	66	13	71	97
	Average for 6 rabbits	50	50	63	1	31	54	47	−2	38	86
D	Average for 4 steers	62	70	76	63	67	68	68	38	72	97
	Average for 6 rabbits	53	56	70	56	31	56	49	29	38	86
	S.D. for steers	1.00	.96	.91	6.05	1.64	1.03	1.09	3.63	2.48	2.17
	S.D. for rabbits	.99	1.28	1.19	6.81	2.96	1.72	1.71	2.76	2.46	3.17

* Total carbohydrates = nitrogen-free extract + crude fibre.
† Other carbohydrates = dry matter − (ash + protein + ether extract + lignin + cellulose).

ibility of the herbage, it will be seen that rabbits digest dry matter from 71 to 85% as efficiently as did the steers.

In order to facilitate the comparison of the digestibilities of the different fractions of the feed, the ratios between the digestion coefficients for each fraction and the dry matter digestibility were determined and are given in Table 3. On this basis it becomes evident that, relatively, rabbits digest the crude protein of their diets consistently somewhat better, and the crude fibre, total carbohydrates and cellulose less well than do steers. Organic matter and lignin also show somewhat lower relative digestibility by the rabbits. The relative figures in trials B, C, and D, are in good general agreement with those in trial A.

TABLE 3.—DIGESTIBILITY OF FEED FRACTIONS RELATIVE TO THE DIGESTIBILITY OF DRY MATTER

Trial	Animals	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract	Total carbohydrates	Lignin	Cellulose	Other carbohydrates	Dry matter
A	4 steers	1.06	1.18	.47	1.03	1.06	1.05	.53	1.07	1.45	1.00
	5 rabbits	1.01	1.43	.43	.52	1.00	.86	.40	.72	1.38	1.00
B	4 steers	1.06	1.10	.49	1.10	1.06	1.07	.21	1.13	1.39	1.00
	6 rabbits	1.02	1.37	.69	.47	1.04	.86	.12	.55	1.41	1.00
C	4 steers	1.06	1.16	.11	1.05	1.08	1.06	.21	1.15	1.56	1.00
	6 rabbits	1.00	1.26	.02	.62	1.08	.94	−.04	.76	1.72	1.00
D	4 steers	1.13	1.23	1.02	1.08	1.10	1.10	.61	1.16	1.56	1.00
	6 rabbits	1.06	1.32	1.06	.58	1.06	.92	.55	.72	1.62	1.00

The correlations between the digestibility of protein and between that of lignin by rabbits and steers are highly significant; but in so far as the "carbohydrate" fractions are concerned the two species are not in step in apparent digestibility as measured by conventional methods. There are doubtless several reasons for this, among which the limitations of crude fibre and nitrogen-free extract determinations in measuring nutritive value are doubtless important. Trends during the grazing season, in gains in live weight of grazing steers[1] and that of rabbits subsisting on clippings representing successive stages of pasture herbage, are similar. This leads to the conclusion that the major difficulty must lie with our present method of chemically describing the feeding value of such herbage.

It would seem that the starting point in the solution of this problem would be in a more satisfactory partition of the carbohydrates. Until an improvement in this direction is made, the possibility of assessing the value of a laboratory animal as a "pilot" for steers in pasture studies must be determined on biological response rather than on methods involving chemical description of the herbages consumed.

SUMMARY

Certain studies of the nutritive value of pasture herbage would be much facilitated if some "pilot" animal could be used in place of farm ruminants, especially when growth of animal or digestibility trials were involved.

The data herein contained are the results of a study of the relative ability of steers and rabbits to digest pasture herbage.

In general rabbits digest such diets less completely than steers.

There are high correlations between the two species in the case of crude protein and lignin.

The digestibility of the carbohydrate fractions isolated by the present feeding stuffs analysis does not appear to be predictable for one species from the behaviour of the other. Since rabbits and steers do react comparably with respect to gains in body weight when fed spring grown as compared to mid-summer grown herbage, it would seem probable that a scheme of chemical analysis which isolated fractions of the carbohydrates which are more nearly biological units would facilitate the usefulness of the rabbit as a "pilot" animal in pasture studies.

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APPENDIX TABLE 1.—CHEMICAL COMPOSITION OF FEED AND FAECES

Trial		Moisture	Ash	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract	Total (CH_2O)	Lignin	Cellulose	Other‡ (CH_2O)
A*	Feed	3.95	9.66	90.34	27.05	4.44	17.60	41.25	58.85	16.01	23.18	19.66
	Steer faeces	4.80	18.75	81.25	18.69	8.62	16.62	37.33	53.95	29.39	20.42	4.13
	Rabbit faeces	4.53	10.49	89.51	17.98	5.57	24.64	41.33	65.97	23.84	29.64	13.07
B†	Feed	11.24	9.49	90.51	29.47	3.14	16.78	41.12	57.90	11.15	19.92	26.85
	Steer faeces	3.71	23.46	76.54	22.26	6.84	12.86	34.58	47.44	31.10	13.48	2.86
	Rabbit faeces	7.60	11.84	88.16	18.22	4.12	26.20	39.63	65.82	21.37	29.11	15.34
C†	Feed	13.53	8.74	91.26	27.93	3.33	17.57	42.43	60.00	15.25	21.07	23.68
	Steer faeces	2.93	17.24	82.76	21.03	8.15	16.21	37.37	53.58	35.17	16.24	2.17
	Rabbit faeces	6.55	10.05	89.95	20.40	6.54	24.20	38.81	63.02	30.79	25.84	6.38
D†	Feed	8.45	14.69	85.31	28.42	5.19	14.99	36.71	51.70	18.61	17.55	15.54
	Steer faeces	2.55	33.22	66.78	17.93	5.00	13.07	30.79	43.85	30.00	12.73	1.20
	Rabbit faeces	5.05	21.56	78.44	17.84	4.80	21.90	33.90	54.14	28.02	23.08	4.71

* Trial A: steer faeces average of 4 steers, rabbit faeces average of 5 rabbits.
† Trials B, C, and D: steer faeces average of 4 steers, rabbit faeces average of 6 rabbits.
‡ Other carbohydrates = dry matter − (ash + protein + ether extract + lignin + cellulose).

FIELD EXPERIMENTS WITH WINTER WHEAT GROWN AS A SPRING CROP[1]

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Ever since the discovery by Lyssenko of the process of vernalization, plant breeders and physiologists have delved more into the temperature and light requirements of cereal crops. It is an established fact that winter wheat, as the name implies, must in nature be sown in the fall in order to complete its growth during the subsequent summer. Through artificial treatment of seeds with specific temperatures and moistures, one may transform a winter cereal into a spring crop. Such a treatment is known as the process of vernalization. The main purpose of this study was to ascertain the agronomic behaviour of *vernalized* winter wheat versus spring wheat.

REVIEW OF LITERATURE

A thorough bibliography of the work dealing with vernalization and phasic developments of plants was given by the Imp. Bureau of Plant Genetics, Bull. XVII, 1935 (14). Purvis, Gregory and co-workers (2, 8, 9) have published a number of papers on various phases of vernalization of cereals and their findings are of great interest in the physiological field of work. Several authors, McKinney and Sando, (6), Lojkin (4) and others have found that vernalization of spring cereals appears to be of no agronomic advantage. Lojkin (4) also claims that field germination is usually impaired from 10 to 20% in both winter and spring wheats when "vernalized". Martin (5) reports that naturally vernalized winter wheat yielded 1.5 bushels less than spring wheat and 8.4 bushels less than early fall sown winter wheat. Russian authors (3, 12) reported that winter wheats ripened under low temperature conditions will carry over a natural vernalization effect in the D^1 (1st descendant) generation.

MATERIAL AND METHODS

The winter wheats used were of varied agronomic values, some being hardier, or earlier, or higher yielders than others. The experiment usually consisted of 8 treated winter wheat varieties and 4 untreated spring wheats.

The seeds for all tests were vernalized at the Cereal Division, Central Experimental Farm, Ottawa. Both the treated material and the untreated were grown at the Experimental Stations at Beaverlodge, Alta. (1936 to 1939), and at Scott, Sask. (1939). Beaverlodge was chosen because of the early fall frosts which frequently occur in northern latitudes; and it was hoped that they would serve to test the relative mature plant hardiness of the different varieties. Scott was chosen because of its position in the drought area of Saskatchewan.

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Seeds of winter wheat varieties were soaked at room temperature of about 70° F. for 16 hours, and the moisture reduced through fanning to 50% of the dry weight before germination. Each lot of seed was then removed to a cooler room for further germination for a period of 24 to 48 hours. After the seed coat was barely pierced by the plumule, all treated material was removed to a cold storage, operating at a temperature of 36° F. Each week the moisture was checked by weighing the samples; thus a uniform percentage was maintained throughout the 65-day treatment.

All varieties on which yield and related data were taken grew in randomized replicated rod row plots, each consisting of 5 rows. The analysis of variance method was used for calculations of the statistics dealing with the experiments (Snedecor, 13).

RESULTS OF EXPERIMENTS

In Table 1 the results obtained at Beaverlodge, Alta., for the year 1936 are recorded.

TABLE 1.—VERNALIZATION TEST—WINTER WHEAT—BEAVERLODGE 1936 (60 DAYS OF TREATMENT)

Variety	Days to mature	Yield in bushels per acre	Variety	Days to mature	Yield in bushels per acre
1. Canus	118.0	54.9	7. Kanred	126.0	58.5
2. Thatcher	117.0	52.9	8. Crail Fife	137.0	34.4
3. Marquis Check	119.0	53.6	9. Kharkov MC 22	137.0	28.7
4. Marquis Treat.	118.0	54.6	10. Minturki	129.0	34.0
5. Reward 22-42	119.0	35.4	11. D. G. Chaff	127.0	30.9
6. Turkey Red	126.0	59.7	12. Yaroslav	137.0	18.7

Standard Error of Variety Mean 2.78.
Mean of Variety = 43.06 bushels.
Necessary Diff. = 8.34 bu.

Co. of Variability in % = 12.93.
F value = 25.08.
5% point = 2.14.

The seed was sown on May 7 and the earliest spring varieties did not ripen until September 7. All varieties suffered some frost damage and received inferior grades. Among the winter varieties, Minturki proved somewhat superior in its resistance to frost. It is evident that Turkey Red and Kanred, two similar varieties, behaved extremely well in yielding ability. The D^1 generation of the above winter wheats showed a distinct effect of low temperature ripening; *e.g.*, Turkey Red and Kanred headed 50% without further treatment while the checks failed to elongate (Russian workers 3, 12).

The experiments recorded in Tables 2 and 3 are duplicate tests seeded May 1 and May 13, respectively. These tests were planned to give more information on mature plant frost resistance. Unfortunately, however, they all escaped early fall frosts. In each case was included a Turkey Red Check in order to ascertain whether any natural vernalization occurred in the field.

TABLE 2.—VERNALIZATION TEST—WINTER WHEAT—BEAVERLODGE 1937
FIRST DATE OF SEEDING

Variety	Days to mature	Yield in bushels per acre	Variety	Days to mature	Yield in bushels per acre
1. Canus	118.5	24.1	7. Crail Fife	127.0	32.2
2. Thatcher	114.7	23.8	8. Kharkov MC 22	128.0	24.7
3. Marquis E'32	117.7	22.2	9. Minturki	128.0	32.2
4. Reward 22–42	111.0	15.7	10. D. G. Chaff	128.0	30.1
5. Turkey Red	127.0	28.9	11. Yaroslav	132.0	23.4
6. Kanred	127.0	29.5	12. Wheat × Rye	127.0	27.6

Standard Error of Variety Mean 2.21.
Mean of Variety = 26.20 bushels
Necessary Diff. = 6.63 bu.
Co. of Variability in % = 16.87.

F value = 4.67.
5% point = 2.14.
(Turkey Red Spring sown not vernalized 13.5 bu. per acre.)

TABLE 3.—VERNALIZATION TEST—WINTER WHEAT—BEAVERLODGE 1937
SECOND DATE OF SEEDING

Variety	Days to mature	Yield in bushels per acre	Variety	Days to mature	Yield in bushels per acre
1. Canus	124.0	27.3	7. Crail Fife	132.3	32.2
2. Thatcher	118.0	28.7	8. Kharkov MC 22	134.7	30.1
3. Marquis E'32	121.0	25.4	9. Minturki	133.0	32.7
4. Reward 22–42	114.0	17.0	10. D. G. Chaff	135.3	29.9
5. Turkey Red	135.7	27.8	11. Yaroslav	139.5	24.7
6. Kanred	134.3	33.1	12. Wheat × Rye	135.0	31.2

Standard Error of Variety Mean 1.11.
Mean of Variety = 28.34 bushels.
Necessary Diff. = 3.33 bu.
Co. of Variability in % = 7.82.

F value = 16.17.
5% point = 2.14.
(Turkey Red Spring Sown not vernalized = 4.41 bu.)

From Tables 2 and 3 it may be seen that there occurs a natural vernalization factor, as the Turkey Red Check yielded 13.5 bushels per acre in comparison with 4.4 bushels in the second date of seeding. It is apparent from the data that several winter wheats significantly outyielded the spring wheats. Kharkov MC 22 and Wheat × Rye behaved similar to the spring wheats as regards increased yields in the second date of seeding. The span in maturity of both dates of seeding is comparable and points to the fact that vernalization was complete.

During the season of 1938 another group of 9 varieties of winter and 3 varieties of spring wheat were seeded on May 6 at Beaverlodge, Alta., (Table 4).

TABLE 4.—VERNALIZATION TEST—WINTER WHEAT—BEAVERLODGE 1938

Variety	Days to mature	Yield in bushels per acre	Variety	Days to mature	Yield in bushels per acre
1. Canus	115.5	20.3	7. Kharkov MC 22	122.0	22.1
2. Marquis E '32	114.3	20.6	8. Tenmarq	121.0	27.0
3. Reward 22–42	108.0	16.5	9. Minturki	122.0	22.2
4. Kanred	122.0	24.9	10. Purple Straw	119.5	20.2
5. Cheyenne	122.3	25.5	11. Red Hart	120.3	21.9
6. Kawvale	116.7	22.8	12. Wheat × Rye	120.3	23.5

Standard Error of Variety Mean 2.46.
Mean of Variety = 22.30 bushels.
Necessary Diff. = 7.38 bu.

Co. of Variability in % = 22.06.
F value = 6.33.
5% point = 2.14.

The data in Table 4 indicate that on the average the winter wheats were superior in yielding ability. Kawvale was almost as early as the latest spring wheat. The grain harvested from this crop was of better grade than from any previous test, consequently a quality test was conducted and results recorded in Table 5.

TABLE 5.—QUALITY TEST OF WINTER AND SPRING VARIETIES GROWN TOGETHER IN VERNALIZATION EXPERIMENT—BEAVERLODGE, ALTA., 1938

	Probable grade	Test weight per bush.	Proetin, %	Loaf volume in C.C.
Canus	3°	66.3	14.5	728
Marquis E '32	3°	66.1	13.8	800
Reward 22–42	3°	66.3	16.3	988
Kanred	3 A.W.	66.9	13.7	703
Cheyenne	4	66.4	11.8	680
Kawvale	2 A.W.	64.1	14.6	750
Kharkov MC 22	4	64.2	14.6	790
Tenmarq	2 A.W.	65.8	12.7	630
Minturki	2 A.W.	65.1	14.3	810
Purple Straw	4	65.5	13.5	675
Red Hart	2 A.W.	65.0	12.6	728
Wheat × Rye	4	65.3	13.4	768

According to the data in Table 5, it is concluded that spring sown winter wheats when vernalized may produce satisfactory commercial milling samples.

A duplicate test was conducted in 1939 at Beaverlodge, Alta., the early fall frost area, and Scott, Sask. in the drought belt. (Tables 6 and 7).

TABLE 6.—VERNALIZATION TEST—WINTER WHEAT—BEAVERLODGE, 1939

Variety	Days to mature	Ave. yield in bus. per acre	Variety	Days to mature	Ave. yield in bus. per acre
1. Canus	107.7	26.1	7. Kharkov MC 22	116.5	22.3
2. Marquis E '32	108.3	21.7	8. Tenmarq	113.5	22.2
3. Thatcher	105.3	26.7	9. Turkey Red	114.3	18.5
4. Bald Rock	113.5	21.6	10. Minturki	113.5	24.8
5. Cheyenne	114.0	20.9	11. Wheat × Rye	114.7	22.9
6. Kawvale	114.0	13.3	12. Quivira	112.3	19.6

Standard Error of Variety Mean 1.59.
Mean of Variety = 21.71 bushels.
Necessary Diff. = 4.77 bu.

Co. of Variability in % = 14.6.
F value = 4.61.
5% point = 2.14.

TABLE 7.—VERNALIZATION TEST—WINTER WHEAT—SCOTT, 1939

Variety	Days to mature	Ave. yield in bus. per acre	Variety	Days to mature	Ave. yield in bus. per acre
1. Canus	101.0	20.8	7. Kharkov MC 22	112.8	14.7
2. Marquis E '32	103.0	18.0	8. Tenmarq	111.3	16.5
3. Thatcher	97.0	20.3	9. Turkey Red	111.8	16.0
4. Bald Rock	113.3	14.0	10. Minturki	110.0	16.3
5. Cheyenne	113.0	17.8	11. Wheat × Rye	109.8	16.6
6. Kawvale	111.8	11.0	12. Quivira	108.5	14.9

Standard Error of Variety Mean 1.05.
Mean of Variety = 16.4 bushels.
Necessary Diff. = 3.15 bu.

Co. or Variability in % = 12.8.
F value = 6.45.
5% point = 2.14.

The observations made from these data are quite conclusive, and definitely demonstrate that in 1939 there was no advantage in favour of the winter wheats.

RESULTS

From the foregoing data, it seems apparent that spring grown winter wheats outyielded spring varieties in two out of four years. In taking the average yield per acre for four tests of Marquis (spring) and Kanred (winter) it is found that they yielded 30.4 bushels and 35.2 bushels per acre, respectively. The commercial milling qualities of the hard red winter wheats proved satisfactory under spring grown conditions.

DISCUSSION

It is possible that in 1936 the varieties Kharkov MC 22, Yaroslav and Crail Fife were insufficiently vernalized, since the period from planting to harvest exceeded the normal difference in maturity of these varieties occurring in the subsequent tests (Purvis and Gregory 8). From the farmers' point of view, it seems impractical to consider growing winter wheats as a spring crop under agricultural conditions in Canada where many suitable spring wheats are available. This opinion is also shared by other workers, McKinney and Sando (6) and Martin (5). The plant breeder is able to make varied uses of the principle of vernalization in the breeding program, e.g., matching of blooming periods for crossing purposes and speeding up filial generations (Peltier and Kiesselbach 7). According to Purvis (9) and work done at the Cereal Division, Central Experimental Farm, the F_1's of crosses between spring and winter forms involving Petkus winter rye and winter wheat varieties grown in these experiments are either partially or completely dominant for spring habit. It appears that the physiological substance responding to vernalization is quantitative rather than qualitative, because, as the process increases in duration to a certain point, heading occurs earlier. The authors' unpublished data and work of other investigators, Purvis and Gregory (8), Lojkin (4), and Russian workers (10, 11), found that vernalization is ineffective with the earlier spring cereals.

SUMMARY

1. Several winter wheat varieties responded favourably to low temperature or vernalization treatment, when kept at 50% moisture over a period of 65 days at 36° F.

2. In 1936, all varieties ripened during low temperatures and were frost damaged, but Minturki proved slightly superior in resistance to frost. The D_1 generation of Turkey Red and Kanred showed a vernal effect by heading 50% without further treatment, while the checks failed to elongate. These var.eties also were quite similar in yielding ability and were on a par with the spring wheats.

3. Dates of seeding in 1937 showed that untreated check plots of Turkey Red were subjected to natural vernalization in the soil, yielding 13.5 bushels per acre in comparison with 4.4 bushels from the second date of seeding. Several of the winter wheats significantly outyielded the spring varieties.

4. A quality test conducted in 1938 proved the spring grown winter wheats to be of satisfactory milling qualities. The yields of grain were significantly above those of spring wheat.

5. Duplicate tests conducted at Beaverlodge, Alta., and Scott, Sask., during 1939 gave no conclusive information on frost and drought resistance of these varieties.

6. Vernalization of winter wheats is of interest to the plant breeder in matching blooming periods and hastening filial generations, as well as increasing the field of varieties for investigation under comparable growing conditions. The growing of winter wheats in the spring is of no practical value to the farmer.

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MAGNESIUM DEFICIENCY OF APPLE TREES IN SAND CULTURE AND IN COMMERCIAL ORCHARDS[1]

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Severe cases of undoubted magnesium deficiency of apple trees in certain commercial orchard areas have been observed during the last two years. In view of the immediate practical importance of the problem, the symptoms of the trouble and some associated conditions are discussed.

OCCURRENCE, SYMPTOMS AND CONTROL MEASURES OF MAGNESIUM DEFICIENCY IN CROP PLANTS

Magnesium deficiency of crop plants causes characteristic foliage symptoms which may vary in detail with different species and even with different varieties, though all show points in common. The most general symptom is that of chlorosis and premature fall of older leaves, while another independent or accompanying symptom is the necrotic browning and death of intervenal tissue.

Various crop plants grown on the soils of the Atlantic Coastal Plain of the United States appear to be especially subject to disorders caused by deficiency of magnesium. The most outstanding disorder due to a deficiency of magnesium is sand-drown of tobacco (7). This name is given to a characteristic chlorosis of the tobacco plant which occurs in aggravated form on sandy soils after heavy leaching rains. The disorder is described as follows: the symptoms are usually more marked on the lower leaves; there is a loss of the green colour at the tip, margin and between the veins of the leaf; the veins retain their normal green colour long after the area between the veins becomes almost white (5). The need for magnesium for this crop is readily met by the use of sulphate of potash containing magnesia, or by applying lime containing magnesia. Sand drown has also been encountered in important tobacco growing areas in Canada where it has been associated with low available magnesium content of the soil (8). The potato is another crop which is commonly affected. The disorder is characterized by a chlorotic condition of the foliage with the lower leaves affected most seriously. A deficiency of available magnesium in the soil is associated with excessive rainfall on soils high in organic matter or on light acid soils whether or not the soil is well supplied with organic matter (1).

It has been recommended that on soils with a reaction below pH 5.0 a finely divided dolomitic lime at a rate sufficient to bring the soil up to a reaction of pH 5.0 or 5.3 should be applied. On soils in which the reaction is too high to allow any addition of magnesium to be made through liming, addition of fertilizer containing magnesium from a soluble source in a sufficient quantity to allow 20 to 30 lb. MgO per acre should be used (3). In Canada, magnesium deficiency has been recorded in potatoes in New Brunswick, and it was found that the deficiency could be corrected by adding 60 to 100 lb. of magnesium sulphate per acre to the soil. Spraying the potato foliage with magnesium sulphate also corrected the disorder (13).

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Carolus (4) has reported a large number of vegetable crops to be affected by magnesium deficiency. Application of dolomitic fertilizer at the rate of 2000 lb. per acre, or fertilizer containing 1% of soluble magnesium from kieserite, to 16 vegetable crops increased the yields from 1% with onions to 92% with turnips. Dolomitic limestone gave the best results on the lighter soils. Magnesium deficiency has also been reported as causing bronzing of citrus (2) sand-drown of cotton (6) and chlorosis of corn (9). In corn the chlorotic strips of intervenal tissue alternate with the green veins.

As a result of sand culture experiments Wallace reported that magnesium deficiency of apple trees produced a typical foliage blotch. This symptom was described as the death of large patches of tissue in the centre of the leaves, which patches became brown in colour. The affected leaves fell, the trees losing all their foliage except a little at the tips (14). He later pointed out that the portion of the leaf affected may vary even for different varieties of apples; Cox's Orange Pippin and Allington Pippin tend to show intervenal tissue breakdown in blotches in the centre of the leaf around the midrib, whilst in Bramley's Seedling the majority of the leaves may be affected first around the margins (15). Wallace also presented chemical data which demonstrated that a low magnesium content may be accompanied by relatively high amounts of calcium and potassium or on acid soils a low amount of calcium with very high potassium content. This relationship of potassium and magnesium has been confirmed by other workers who state that heavy applications of potash are conducive to magnesium deficiency in various crops, including corn and potatoes (9, 10). A further contribution by Wallace (16) reports the occurrence of magnesium deficiency in apple orchards at three centres in England. Foliage symptoms were similar to those secured with sand culture experiments. Three successive annual applications of 400 lb. of magnesium sulphate per acre did not appreciably affect the magnesium content of the leaves. It is suggested that although annual plants deficient in magnesium have been shown to respond quickly to dressings of fertilizers containing magnesium, fruit trees may recover only very slowly.

EXPERIMENTAL

Sand Culture Experiment

Trees of three varieties, McIntosh, Fameuse and Melba, were employed in the experiment. These trees had all been budded to Malling Type XVI rootstock three years previously and had been retained in the nursery. Trees were planted in nutrient free sandstone in unglazed but waxed 12-inch pots.

The magnesium free nutrient solution was made up in quantities of 40 gallons. Details of its composition are as follows:—

Potassium sulphate	13.5687 grams
Monoammonium phosphate	23.9379 grams
Calcium nitrate	35.9042 grams
Calcium chloride	11.9378 grams
Ammonium nitrate	20.7840 grams
Manganous sulphate	0.1400 grams
Boric acid	1.0388 grams
Ferric chloride	2.6397 grams

The concentrations of the elements as parts per million in the solution are as follows: nitrogen 80, phosphorus 26.6, potassium 33.5, calcium 57, sulphur 13.7, manganese 0.19, boron 1.0, iron 3, chlorine 41.4.

The solution was applied daily at the rate of 500 cc. per pot until June 11, when the daily application was increased to 1000 cc. per pot.

Growth and Foliage Characters

No significant reduction in growth or distinctive foliage symptoms occurred in the first three seasons, during which the experiment was conducted. This delay in the onset of deficiency symptoms may be due to the fact that the experimental trees were grown in a heavily fertilized nursery for two years previous to treatment and had thus accumulated large reserves. They were also budded on a very vigorous rootstock.

In the fourth season, the shoot growth made by all three varieties was only 50% of that made by similar trees receiving a complete nutrient solution. In the early part of the season the quality of the foliage was similar to that of the complete nutrient series but by the end of July large brown patches or blotches of dead tissue began to appear in the centre or around the margin of basal older leaves of numerous shoots. This symptom is similar to that described by Wallace (14) and is illustrated in Plate I, 5. In this season deficiency symptoms did not progress beyond the point described nor did any marked premature defoliation occur.

During the early part of the fifth season the growth was vigorous, the leaves normal in colour and tending to be large. Foliage symptoms did not appear until about the third week in July, but by the end of the first week of August had become pronounced and severe. The symptoms first appeared at the base of the current year's growth and progressed upwards. In the variety Melba, the most prominent foliage symptom was a yellowing, beginning around the leaf margins and progressing inwards towards the midrib. The veins and a small area of tissue next to the veins remained green, producing an effect of radiating narrow green and wide yellow bands (Plate I, 2). This is quite similar to symptoms of magnesium deficiency on tobacco and corn. The yellowed bands of tissue ultimately died and became brown in colour (Plate I, 1). Similar affected leaves sometimes occurred on the varieties Fameuse and McIntosh, although as often as not marginal or centre intervenal blotches appeared without any previous or accompanying chlorotic bands of tissue (Plate I, 3 and 4). When marginal patches of dead tissue occurred, without any previous or accompanying intervenal chlorotic bands, the necrotic area was surrounded by a narrow region of light green to yellow green tissue (Plate I, 3). This characteristic helps to distinguish between marginal breakdown of tissue due to magnesium deficiency and that due to a deficiency of potassium. In the latter case, the tissue bordering the necrotic area is a distinctive olive brown. By the middle of Spetember the dead patches involved a large area of individual leaves (Plate 1, 4). The leaves became rolled and premature defoliation of the older basal shoot leaves took place (Figure 1).

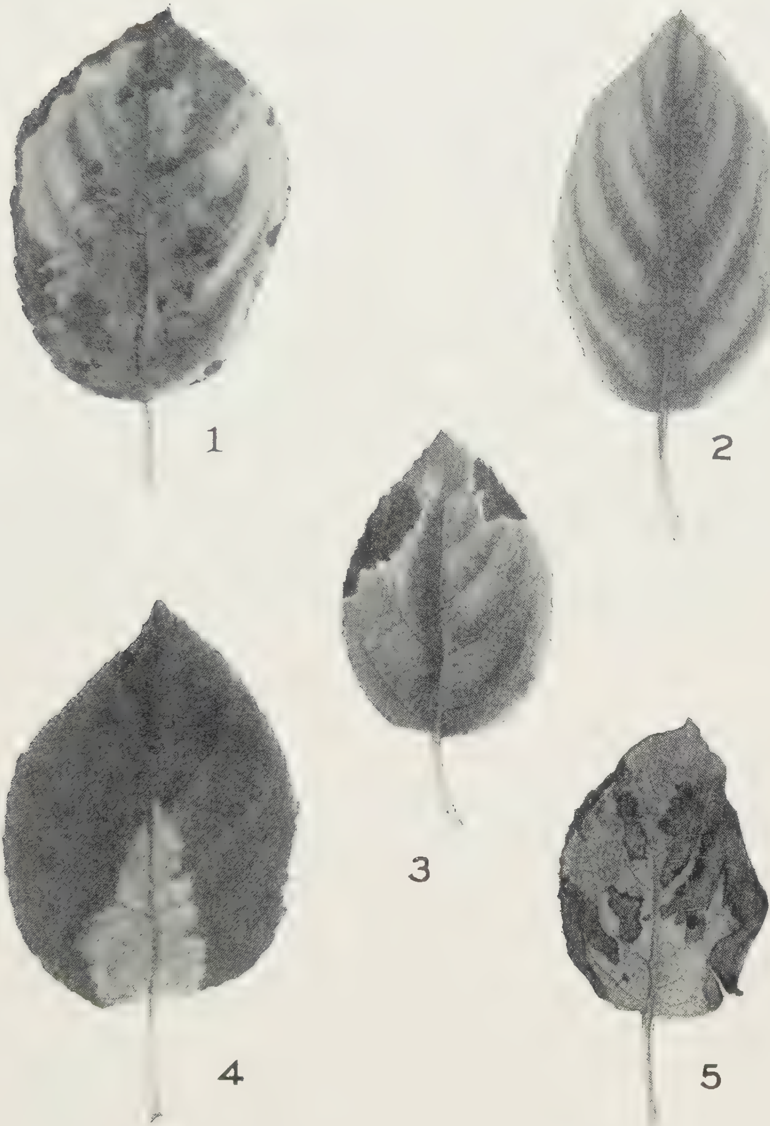

Plate I. 1 and 2: Typical deficiency symptoms of the variety Melba. The occurrence of intervenal bands of chlorotic tissue as depicted in 2 is followed by the death and nut brown colouration of such tissues as shown in 1.

3 and 5: In the Fameuse and McIntosh varieties, marginal or central intervenal blotches of dead brown tissue may occur without any previous or accompanying chlorotic bands, but the dead area is surrounded by a narrow region of yellow green tissue.

4: Fameuse variety. By the middle of September, the dead brown patches involve a large area of individual leaves.

Magnesium Deficiency in Commercial Apple Orchards

Due to the effects resulting from magnesium deficiency on apple trees in sand culture, a close watch has been kept on the possibility of this deficiency being evident in commercial orchards. Until the season of 1938 no clear cut instance of magnesium deficiency in commercial apple orchards had been noted, although there had been several suspected cases in which the trees had a very small proportion of their leaves affected with patches of dead tissue similar to that depicted in Plate 1, 5. In 1938, early in the month of August, our attention was drawn to the occurrence of a very marked foliage disorder occurring in one of the largest apple growing centres of the province of Quebec. The early part of the growing season was characterized by heavy, leaching rains. The disorder was general throughout the district and in many cases was extremely severe. The disorder was especially severe on the variety Melba and on this variety the symptoms were identical with those produced and described by magnesium deficiency in sand culture (Plate 1, 2). The symptoms found on the varieties Fameuse and McIntosh were similar to those described as resulting from magnesium deficiency in sand culture; marginal blotches and intervenal bands of necrotic tissue were more prominent than intervenal bands of chlorotic tissue. By early September a large proportion of the older leaves were affected with large areas of dead tissue. Such leaves became rolled and premature defoliation commenced (Figure 2).

In the variety Lawfam, intervenal chlorosis was followed by the disappearance of chlorophyll from the secondary veins and surrounding tissue so that the entire leaf had a white bleached appearance. Dead necrotic areas occurred on the margin or in the centre of the leaf (Figure 3).

Soil Characteristics

The Quebec Soil Survey Committee report that the main orchard soil in this area is a dark brown loam; the soil is quite acid (pH 4.6 to 5.3) and occasionally traces of podsolization can be found. The surface layer is rich in organic matter and total nitrogen. The subsoil is quite porous and friable to a depth of 2 to 3 feet, where it becomes very hard and compact. The compact subsoil restricts the free vertical movement of the water and the root penetration. Calcium and magnesium content are low with a satisfactory potassium level (12).

Samples of surface soil were taken from 5 orchards affected with the disorder and determinations made of available potassium, phosphorus, magnesium and calcium according to the method of Morgan (11). The results shown in Table 1.indicate a low status for available magnesium and lime. The soil reaction is definitely acid.

TABLE 1

Potassium	Phosphorus	Magnesium	Calcium	pH
1 medium – low	Medium	Very low	Low	5.0
2 medium – low	Medium	Medium	Low	5.0
3 very high	Medium	Low	Low	5.2
4 low	Medium	Low	Low	5.0
5 high	Medium	Low	Low	5.3

FIGURE 1. Fameuse variety in sand culture. Rolling and premature defoliation of the older basal leaves of shoots.

FIGURE 2. Deficiency symptoms in a commercial apple orchard by the middle of September.

FIGURE 3. Lawfam variety. Intervenal chlorosis is followed by the disappearance of chlorophyll from the secondary veins and surrounding tissue. Dead brown areas occur on the margins or in the centres of the leaves.

Samples of affected leaves from the same orchards were taken for analysis. In Table 2 these analyses are compared with the average analysis of normal leaves of the same variety. The outstanding result is the

TABLE 2.—ASH CONSTITUENTS IN LEAVES AFFECTED WITH TYPICAL SYMPTOMS COMPARED WITH AVERAGE ASH CONSTITUENTS OF NORMAL LEAVES. SEASON 1938

	Ash constituents as per cent ash			
	K_2	CaO	MgO	P_2O_5
1 Orchard 1	31.45	28.43	2.50	5.54
2 Orchard 2	43.86	18.21	1.76	7.73
3 Orchard 3	35.65	25.24	1.19	6.27
4 Orchard 4	31.26	29.25	1.39	6.19
5 Orchard 5	32.34	28.15	2.49	6.79
6 Normal foliage	25–30	20–25	5–7	6–8

very low magnesium content of leaf samples affected with the symptoms previously described and diagnosed as magnesium deficiency. It will be seen that the percentage of magnesium in the ash ranges from 1.19 to 2.50, whereas the percentage found in the ash of normal leaves is 5 to 7. The percentage of calcium and phosphorus compares quite well with the average content in normal leaves, while the potash content is slightly higher.

Remedial Treatments

In the spring of 1939 soil applications of magnesium sulphate, sulphate of potash magnesia, and dolomite limestone were made to individual trees affected in 1938 in an endeavour to correct the deficiency. In annual crops magnesium deficiency has been readily corrected by applications of magnesium sulphate, kieserite or sulphate of potash magnesia at rates supplying 20 to 30 lb. of soluble magnesia (MgO) per acre or insoluble compounds such as magnesia limestone and dolomite at 1000 to 2000 lb. per acre. On the soil concerned, the logical procedure would be to employ the latter compounds since they would tend to reduce soil acidity and to supply calcium. However, since a quick response to magnesium applications was hoped for, the more soluble compounds were also employed.

Rates of Applications

Magnesium Sulphate: 1, 1½, 2, and 3 lb. to the area of soil occupied by the roots of an individual tree. Considering that there were 35 eight-year-old trees to an acre and estimating that the root systems of these trees extend over one-third of the total area, the per acre applications are 17.1, 25.7, 34.2, and 51.4 lb. of MgO.

Sulphate of potash magnesia and dolomite limestone were applied to the tree root area at rates which provided the same quantities of MgO per acre. Dolomite limestone was applied also at rates which provided 105, 210 and 315 lb. of MgO per acre.

Growth Characters in 1939

Early in the season the growth and quality of the foliage was satisfactory, but towards the latter part of June considerable burning and scorching of the foliage was evident. At the time of its occurrence spray materials were considered responsible. It is interesting to note that Wallace (16) points out the possible importance of magnesium deficiency in problems of spray injury. Typical magnesium deficiency symptoms were not evident until early in August but by the first week of September, chlorosis, necrosis, rolling and premature defoliation was pronounced in a large number of orchards in the district (Figures 2 and 3). None of the treatments described effectively controlled the disorder in the year of their application. The disorder appeared to be slightly less severe on trees which had received a soil application of 3 pounds of magnesium sulphate.

Magnesium Content of Leaf Petioles and Terminal Shoots

Six weeks after application of the various soil treatments magnesium was determined colorimetrically in a 2% acetic acid extract of leaf petioles and terminal shoots of treated and untreated trees and of similar samples collected from four other centres of apple production, where the described disorder had never been observed.

	Treatment	P.p.m. of magnesium
Petioles	Check	250
Shoots		750
Petioles	Sulphate of potash magnesia 5 lb. per tree	250
Shoots		750
Petioles	30 lb. dolomite limestone per tree	125
Shoots		750
Petioles	$1\frac{1}{2}$ lb. magnesium sulphate per tree	125
Shoots		750
Petioles	Centre I	625
Shoots		1500
Petioles	Centre II	750
Shoots		1500
Petioles	Centre III	500
Shoots		1000
Petioles	Centre IV	625
Shoots		1500

In no case is there an increased level of magnesium in the plant extract due to the application of a magnesium compound to the soil. The magnesium level is considerably lower than that found in four other centres where the disorder has not occurred.

CONCLUSIONS AND SUMMARY

A brief review is given of the occurrence, symptoms and control measures found effective for magnesium deficiency of various crop plants.

The effect of magnesium deficiency on the foliage and growth of the Melba, Fameuse and McIntosh varieties of apple trees when grown in sand culture is described and illustrated.

The occurrence of magnesium deficiency in commercial apple orchards is reported, and the growth and foliage symptoms compared with those produced by a magnesium deficiency in sand culture.

Soil conditions associated with the occurrence of magnesium deficiency are reported; dark brown loam soils decidedly acid in reaction, occasionally showing traces of podsolization; the surface soil rich in organic matter and total nitrogen; calcium and magnesium content low with a satisfactory potassium level.

A comparison is made between the composition of the leaves of terminal shoots from trees affected with typical symptoms and the composition of leaves from average normal trees of the same variety. Leaves from affected trees have a very low magnesium content, a normal phosphorus and calcium content and a somewhat higher potassium content than leaves from average normal trees.

Attention is drawn to the possible influence of magnesium deficiency in increasing susceptibility of the foliage to spray damage.

Soil applications of magnesium sulphate, sulphate of potash magnesia and dolomite limestone did not affect the magnesium content of the leaf petioles or the terminal shoots or prevent the disorder from occurring in the year of their application.

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TYPE-OF-FARMING AREAS IN SASKATCHEWAN[1]

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While wheat growing is the dominant enterprise on most Saskatchewan farms, it is not the only type of farming carried on in Saskatchewan. Throughout the park belt and in the southwest part of the Province there are crop enterprises and combinations of crop and livestock enterprises in addition to wheat production, which make up the typical farm organization in these areas.

Farmers tend to adjust their farm organization and practices to the natural factors of soil, topography, climate and to distance from market. It is an attempt on their part to obtain the highest net return from the resources at their command. This adjustment is undertaken consciously or unconsciously and represents the application of the economic principle of comparative advantage.

Objective of the Study

Briefly, the objective of this study was to define the types of farming in Saskatchewan and to determine the boundaries of the type-of-farming areas. It gives a wide view of the field and provides a background of information essential to a correct understanding and interpretation of the economic problems of the Saskatchewan farmer.

Definitions

Type of farming is a term used to describe the typical organization of a group of farms which have a high degree of uniformity in the kinds, amounts and proportions of the crops and livestock handled and in the methods and practices followed in production (1). Types of farming, therefore, are identified by the relative amounts of the productive factors and the combination of enterprises making up the average farm business as well as by the general policy of operating the farm unit. When a type of farming is fairly well concentrated in a certain area, the area may be called a type-of-farming area.

Method of Analysis

Ratios and isopleth maps as outlined by Wellington D. Jones were used to determine the boundaries of each individual type of enterprise and the final type-of-farming areas (2). This method was used in preference to either the productive man-work unit method or the gross income method as a measure of farm type.

Two other type-of-farming studies have been made for Saskatchewan. McArthur used the proportion of total productive man-work units on various enterprises to differentiate type-of-farming areas (3). He used census data of municipalities and drew isopleths to indicate the approximate boundaries of the different types. McArthur's type-of-farming map agrees substantially with the type-of-farming map of this study. The Agricul-

[1] This article is based on "Determination of the Boundaries of the Important Types of Farming in Saskatchewan," Master's Thesis submitted by the author to the Department of Farm Management, University of Saskatchewan. The data for the study were compiled from the 1931 Census of Agriculture. The article is presented as a contribution to methodology in Farm Management.

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tural Branch of the Dominion Bureau of Statistics used the individual farm as the statistical unit and calculated the percentage of gross income from each enterprise on every farm (4).

The ratio method used in this study is a reasonable and practical method and one which has not been widely used in Canada. Ratios of various agricultural phenomena are more significant than the absolute values of the individual enterprise. This is particularly the case in Saskatchewan where there are wide variations in rainfall and temperature and where crop yields consequently show violent fluctuations.

Ratios of a number of economic factors were calculated for each municipality in Saskatchewan. The same ratios were calculated for each of the Prairie Provinces.

TABLE 1.—RATIO VALUES FOR THE THREE PRAIRIE PROVINCES AND LIMITING RATIO VALUES USED IN DEFINING SIGNIFICANT TYPE-OF-FARMING AREAS

	Saskatchewan	Manitoba	Alberta	Prairie Provinces	Limiting value
	%	%	%	%	%
Relative amount of occupied land					
Improved	60.3	56.3	45.5	54.5	—
In all field crops	39.8	38.6	30.8	36.4	—
Relative amount of all field crops in					
Wheat	67.8	44.8	66.0	64.0	—
Oats	19.5	26.0	20.5	20.7	21.0
Barley	6.2	19.2	5.9	8.0	15.0
Rye	2.4	0.9	1.3	1.8	15.0
Other crops	4.1	9.1	6.3	5.5	15.0
	No.	No.	No.	No.	No.
Relative number per 100 acres of all field crops					
Cattle	5.4	11.4	9.3	7.4	10.0
Cows in milk or in calf	2.2	4.8	6.5	3.0	4.0
Swine	4.3	6.7	8.7	6.0	8.0
Sheep	1.3	3.7	6.5	3.2	5.0
Horses	4.5	5.6	7.8	5.1	—
	%	%	%	%	%
Cows in milk or in calf of total cattle	40.3	41.8	39.0	40.2	47.0

The ratio values which were calculated and the isopleth maps which were drawn included the following: relative amount of occupied land improved; relative amount of occupied land in all crops; acres of field crops per farm; relative amount of all crops in wheat, oats, barley, rye and "other crops"; total livestock units per 100 acres of all field crops; numbers of all cattle, cows in milk or in calf, swine and horses per 100 acres of all field crops; and relative numbers of all cattle which were cows in milk or in calf. It must be kept in mind that the rural municipality was used as a unit and consequently any variations within it would not be indicated.

The ratio values were shown on base maps by entering each value in the centre of the rural municipality to which it applied. Isopleth lines were then drawn by interpolation with reference to the figures entered on

the map, in somewhat the same manner as isoheyts are drawn with reference to rainfall maps. Isopleths are simply lines drawn on a map connecting points of equal magnitude. Thus isopleth maps are a convenient method for mapping ratio values. The base maps were of the same size, making it possible to superimpose one upon the other and note any apparent relationships.

Limiting Ratio Values

The ratio at which a certain crop or kind of livestock enterprise was assumed to be of significant proportions was called the limiting ratio value for the enterprise. Table 1 gives the limits used in this study. The relative amount of all crops in wheat was over 50% in all parts of the Province except in a few rural municipalities east of Yorkton and along the northern pioneer settlement fringe. This fact, together with studies conducted by the Department of Farm Management of the University of Saskatchewan, indicates that wheat is the dominant farm enterprise on practically all Saskatchewan farms. Thus no limiting ratio value was used for wheat.

For the three Prairie Provinces combined, the average ratio of the oat acreage to that of all field crops was about 21%. It was felt that, for an area to be considered significant as an oat producing region, it should have at least as great a proportion of all field crops in oats as the average proportion for the three prairie provinces. The figure of 21% of all field crops in oats was therefore used as the limiting ratio for the oat enterprise.

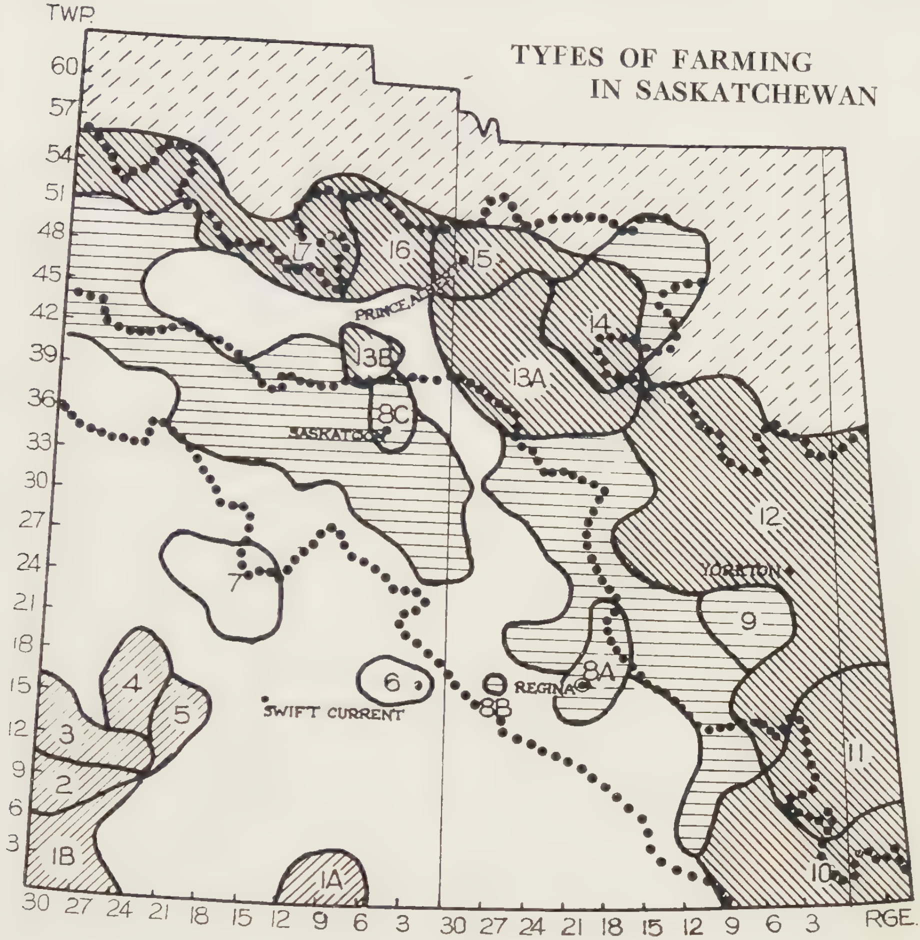
The limiting ratio value used for barley, rye and other crops was 15%. The feed requirements for power purposes on the average sized farm in Saskatchewan were estimated to take the production from about 6 acres of oats for every 100 acres of all crops. As 21 acres of oats per 100 acres of all crops was used as the limiting ratio for oats, this left the yield from 15 acres of oats per 100 acres of all crops to be sold or to be fed to productive livestock. This procedure placed the coarse grains on a fairly comparable basis when defining the boundary for each respective type of farming.

The numbers of each kind of livestock per farm in Saskatchewan are not high. Limiting ratio values close to 50% more than the average for the Prairie Provinces were used in defining the boundaries for areas of each kind of livestock with the exception of dairy cattle. The fluid milk producing regions for the larger cities of the Province were not indicated by this limiting ratio value. Therefore, areas in which the percentage of cows in milk or in calf represented 47% or more of the total cattle were designated as dairy cattle areas.

The northern section of the Province has been recently settled and no definite type of farming has been developed as yet. Therefore, a figure of 50 acres or less of field crops per farm was used to define the boundary for the pioneer fringe area.

Type-of-farming Areas

The final type-of-farming areas map was made by drawing the limiting ratio isopleths, as explained in the previous section, on the same base map. When the isopleth for each limiting ratio value had been placed on the map,



Wheat and Ranching Area
1A, 1B........Wheat and Cattle Ranching
2............ Cattle and Sheep Ranching
3.. ..Wheat, Rye, Sheep and Beef Cattle
4... Wheat, Sheep and Beef Cattle
5... Wheat and Sheep Ranching

Wheat Area
6.............Wheat and Rye
7.............Wheat and Flax

Wheat and Oats Area
8A, 8B, 8C....Wheat, Oats and Dairy Cattle
9.............Wheat, Oats and Rye

Wheat and Mixed or Wheat and General Farming Area
10............Wheat, Oats and Barley
11............Wheat, Oats, Barley, Hogs, Beef and Dairy Cattle
12............Wheat, Oats, Beef and Dairy Cattle
13A, 13B......Wheat, Oats and Hogs
14... .Wheat, Oats, Barley and Hogs
15............Wheat, Oats, Hogs and Dairy Cattle
16............Wheat and Beef Cattle
17............Wheat, Oats and Beef Cattle

Pioneer Fringe Area

Boundaries of Soil-Climatic Zones

FIGURE 1

the boundaries for each area were smoothed out where several ispoleths came close to each other. The final smoothed type-of-farming map for Saskatchewan is shown as Figure I.

Practically all of the brown and dark brown soil zones of the Province are mapped as a wheat type-of-farming area. The exceptions are the cattle and sheep ranching areas of the southwest and areas 6 and 7, centering around Chaplin and Kyle respectively. In a representative rural municipality of area 2, the average size of farm was 1,438 acres with only 82 acres in crop and 1,313 acres in wild pasture. This representative municipality has an average of 84 head of cattle and 25 head of sheep per farm. The average size of farm in a typical rural municipality in area 1 was 504 acres with 233 acres in wheat alone. The average total improved acreage per farm was 452 acres.

The wheat and oats areas may be taken as transitional regions. The average size of farm in two typical rural municipalities in these areas varied from 264 acres to 390 acres per farm. The range in acres of wheat per farm was from 77 to 102 acres for the two respective rural municipalities. The range in oats was from 32 to 59 acres per farm respectively. It will be observed that these areas are mostly in the park belt which has a cool and relatively moist climate.

In all the areas of the park belt, either relatively higher freight rates, or lower grades of wheat, or both, and the weed menace, tend to stimulate production of coarse grains and thus more livestock. There is a gradual increase in total annual precipitation from an average of 13 inches in the southwest to 15 inches in the north and east of the Province. Precipitation for the growing season increases from an average of 7 to 11 inches respectively. A very important point is that evaporation decreases correspondingly. The average frost-free period decreases from 125 to 135 days in the southwest to 105 to 110 days in the northeast. These natural and economic factors result in a wider diversity of crops in the park belt of the northern and eastern parts of the Province which is reflected in more livestock production.

There are three sub-areas (8A, 8B, and 8C), in the wheat and oats area which are located around Regina, Moose Jaw and Saskatoon. In these regions the dairy cattle enterprise is an important part of the average farm business due to proximity to a relatively large urban population.

The wheat and mixed or wheat and general farming areas are all located in the park belt. Other minor enterprises combine with wheat in each respective area to make up the typical farm setup. Area 11 illustrates the diversity of enterprises found in this area. The average size of farm in a representative rural municipality was 497 acres with only 267 acres improved. The wheat acreage was 67 acres, oats 61 acres and barley 38 acres. The average farm in that rural municipality had 19 head of cattle of which 7 were cows in milk or in calf. There was an average of 17 hogs per farm.

Area 14 centering around Melfort is of special interest. The type of farming in this area combines wheat, oats, barley and hogs. In a typical rural municipality the average size of farm was 335 acres with 214 acres

improved. The crops were made up of 84 acres of wheat, 39 acres oats, 27 acres barley and 3 acres of other crops. The productive livestock consisted of 11 head of cattle and 19 hogs per farm.

This study localizes various types of farming in Saskatchewan. It should be clear that the boundaries for each type do not represent a distinct demarcation but rather are guides to indicate the transition from one type-of-farming area to the other.

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STUDIES ON OAT BLAST[1]

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INTRODUCTION AND HISTORICAL SUMMARY

The so-called "blast" or "blindness" of oats is a condition in which the growth of some of the spikelets is inhibited during the development of the panicle so that when the panicle emerges the blasted spikelets are sterile and have a white, papery appearance (Figure 1). These spikelets are present most commonly on the lower branches of the panicle and are of various sizes from almost full size down to the size of a pinhead or less according to the stage of spikelet development when the inhibition of growth took place. Three main theories have been advanced by investigators to account for this condition: (1) that it is the result of injury caused to the developing spikelets by insects; (2) that it is the result of injury caused to the foliage of the oat plant by bacteria and fungi; and (3) that it is caused by the developmental conditions surrounding the growing oat plant. It has further been advanced by some investigators that blast is primarily a varietal characteristic.

The nature of the evidence submitted in support of each of these theories merits brief consideration. That blast is caused by insect injury to the developing spikelets was advanced by Hewitt (6) who attributed the presence of blasted spikelets to the injury by the grass thrips *Anaphothrips striatus* Osborn. He stated that "the adult and larval insects feed upon the developing spikelets and produce complete sterility in the same by sucking the ovaries and feeding on the young anthers." Roebuck (13), in England, found larvae of the frit fly *(Oscinis frit)* feeding among the folded flowers on panicles still enclosed in the swollen sheaths. He pointed out that there are usually three successive broods of fruit flies on the oat crop in England: an early one that injures the tillers, an intermediate one that he believes is associated with blast, and a later one that causes injury to the kernels. Zade (15, p. 195–197) likewise ascribed blast largely to injury caused by several species of insects, including thrips and two species of the frit fly, but admitted that weather conditions may also be contributing factors. Huskins (7) obtained some slight confirmation of a correlation between frit-fly attack and blast but states that "the condition in which spikelets scattered over the head are blind does not, however, seem to be attributable to the frit fly". Rademacher (10) mentioned injuries by the frit fly, thrips, and various other insects among the causes of oat blast. Cunliffe (2), in studies on the relation of *Oscinella frit* Linn. to blast in oats, concluded that in his experiments, sterility was not caused by frit-fly injury, and suggested that it might be a varietal character.

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FIGURE 1. Oat panicles bearing blasted spikelets. Left: A panicle in which the blasted spikelets are largely confined to the lower branches. Right: A more severe condition in which more than half the spikelets are blasted.

The view that blast is the result of foliage destruction caused by bacteria or fungi has been advanced by several investigators including Manns (8) who ascribed it to leaf injury caused by bacterial blade blight of oats, and Arnold (1) and O'Brien and Dennis (9) who attributed it to leaf damage caused by *Helminthosporium Avenae* Eidam. Charlotte Elliott (4) observed blast on oat plants affected with halo blight but was unable to demonstrate a correlation between halo blight and blast. Rademacher (10) stated that blast is sometimes brought about as an indirect result of parasitic injury by *Fusarium* foot rot or by stem rust.

The view that the amount of blast is influenced by the environmental conditions surrounding the oat plant, especially in its later growth stages.

has been expressed by several investigators. According to Huskins (7), Seelhorst (14) showed that the moisture conditions before and during heading exerted a strong influence on the amount of blast. Dry weather prior to and during panicle emergence increased the number of blasted spikelets, particularly if the plants had received abundance of moisture in earlier stages of growth. Zade (15) expressed the opinion that drought conditions shortly before heading and especially at the time of heading may contribute to the amount of blast. In this connection he cited experiments by Bünger who found that as much as 40% of the spikelets remained sterile when the plants were subjected to a dry period at the time of heading.

Elliott (4) suggested that blast was chiefly the result of too much moisture about the developing panicles prior to their emergence from the sheaths, a condition that might be brought about by precipitation at that period. Later observations (5) over a period of three years (1922–1924), however, showed that the severest blast occurred in a year in which precipitation at the time of heading was abnormally low.

Perhaps the most thorough and extensive work on environmental influences is that of Rademacher (10, 11), who investigated the effects of moisture supply, mineral nutrients, and cultural conditions on the development of blast. He expressed the opinion that blast is caused by a disturbance of the sap supply which is frequently a result of moisture deficiency during the period from the formation of the topmost node to the time of heading, and he states further that the effect of drought during this period is much greater if the plants received abundant moisture in earlier stages of growth than if moisture was then deficient. Among other environmental conditions reported by Rademacher that increase the amount of blast may be mentioned unbalanced fertilizer supply, such as deficiency or excess of nitrogen, and certain cultural conditions, including late sowing and too distant or too close spacing of plants. Somewhat similar conclusions concerning the influence on blast of available moisture were reached by Derick and Forsyth (3) who concluded that there are critical periods in the development of the oat plant when the moisture supply influences the percentage of blasted spikelets, the most critical period being between six to eight weeks after seeding, at which time abundant application of water tends to reduce the amount of blast.

It has furthermore been stated by several writers that blast is a varietal character in so far as certain varieties have a far greater tendency to develop blasted spikelets than others. Zade (15) maintained that varieties with light straw and a relatively low moisture requirement produce less blast in response to moisture deficiency than more hydrophilic varieties with stout straw. Cunliffe (2), as mentioned above, suggested that blast might be a varietal character and Huskins (7) concluded that specific genetic resistance to blast exists among oats. Rademacher (12), in a comparison of the amount of blast in 111 oat varieties, concluded that, although the development of blast is largely dependent on external conditions, the degree of development differs from variety to variety and must hence be regarded as a fixed genetic character.

The literature reviewed above would indicate that blast of oats may be brought about by one or the other of several causes, and, as the external conditions surrounding the oat plant differ considerably from one region

to another, it appears possible that the factors chiefly responsible for blast in different regions may not be identical. The object of the work described in the present paper was principally to discover, if possible, what factors were of primary importance in the causation of blast under growth conditions prevailing in the Prairie Provinces of Canada where blast is always present and often severe. As the varieties commonly grown, such as Banner and Victory, are highly subject to blast, there can be little doubt that marked reduction in yield has often resulted from the presence of a large proportion of sterile florets. The experiments reported in this paper have consequently dealt with conditions to which the oat plant is often subjected in the prairie region, such as drought at various stages of growth, attack by rust in the later growth stages, and defoliation, which, in nature, is occasionally brought about by grasshoppers and other causes. Attempts have also been made, by means of field experiments, to discover what cultural conditions are most likely to reduce the amount of blast.

THE EFFECT OF LEAF INJURY ON THE INCIDENCE OF BLAST

A number of investigators have reported a relationship between leaf injury and the amount of oat blast. Manns (8, p. 131), working with bacterial blade blight of oats, concluded that the amount of blast is "more or less directly proportional to the severity of the blight disease". Arnold (1), in a discussion of leaf injury caused by *Helminthosporium Avenae* has stated that the affected plants were characterized by "deaf" ears, a condition attributed to the foliage destruction caused by *H. Avenae*.

O'Brien and Dennis (9) have observed that oat plants, the leaves of which were destroyed by *H. Avenae*, were "unable to fill the full number of spikelets, those at the base of the ear remaining barren and blasted. Under severe conditions the ear of the infected plant may be reduced to a couple of full spikelets only". They concluded that the blasting of spikelets was not due to direct infection by *H. Avenae* but was rather a result of the destruction of the early leaves and the overshadowing of the infected plants by their healthier competitors.

The above observations suggested the idea of carrying out controlled experiments to determine the relationship between defoliation of the oat plant and other forms of leaf injury and the amount of blast. With this object in view a number of experiments were carried out in the greenhouse and in the field.

Greenhouse Experiments on Defoliation

In the first greenhouse experiment 60 pots of Victory oats were planted on September 10, 1935, two plants being grown in each pot. Fifty days later when almost all of the plants were in the 7-leaf stage, defoliation was commenced. The 60 pots were divided into 5 series. In the first series the 4 lowest leaves (the seedling leaf and the next 3 leaves above it) were detached. In the second series 6 leaves were detached. In the third series 6 were detached and subsequently, as new leaves emerged, 2 more leaves were removed to make up a total of 8 leaves detached. In the fourth series 6 of the 7 leaves were detached and, as subsequent leaves emerged, each penultimate leaf was detached until the panicle emerged, when the ultimate (flag) leaf was also detached. The plants of the fifth series were

kept as control plants, no leaves being removed. The results of this experiment, summarized in Table 1, show that the amount of blast increased progressively with increased defoliation from about 50% in the control plants to about 86% in the plants that were completely defoliated.

A repetition of this experiment was carried out in the late winter and spring of 1936. Defoliation was commenced when the plants were in the 6-leaf stage at which time 4 leaves were detached in the first series and 5 leaves in the second and third series. In the last-named series, the sixth and seventh leaves (none of the plants produced more than 7 leaves) were removed when they had fully emerged. The results, which are also expressed in Table 1, agree with those of the first experiment.

Table 1.—The effect of various degrees of defoliation on the percentage of blast in Victory oats

Experiment 1 (Fall)		Experiment 2 (Spring)	
No. leaves detached	Per cent blast	No. leaves detached	Per cent blast
None	49.8	None	10.6
4	66.1	4	9.6
6	73.3	5	33.5
8	74.2	7 (all)	34.2
10 (all)	86.3		

These experiments show clearly that the proportion (percentage) of blasted spikelets may be greatly increased by partial or entire defoliation of the oat plant prior to the emergence of the panicle. In both experiments the total number of spikelets (fértile and blasted) per panicle was significantly smaller in the defoliated than in the control plants.

Table 1 shows that the blast percentages in the first experiment are very much higher than in the second. The control plants of the first experiment showed 49.8% of the spikelets blasted as against 10.6% in the second experiment. As the same variety, and even seed from the same source, was used in both experiments, the differences in percentages of blast must have been due to the different environmental conditions prevailing during the two experiments.

The first experiment was conducted during the autumn months, the seed being planted on September 10. The growing plants were therefore subjected to progressively diminishing daylight. The second experiment was carried out during the late winter and early spring, the seed being planted on January 8. In this experiment, the plants at first grew under conditions of a short day and low light intensity but were presently subjected to the influence of lengthening day and increasing intensity of light. In the first experiment, the plants laid down their spikelet initials under moderately favourable conditions of light but were subsequently faced with more and more unfavourable light conditions. The high proportion of blasted spikelets in the control plants suggests strongly that the progressive diminution in light caused a large number of the younger spikelets to be sacrificed (blasted) to permit full development of the remaining spikelets. In the second experiment, conditions of light were poor during the early phases of growth but improved gradually and spikelet initials were laid

down under moderately favourable conditions of light. Subsequently, however, light conditions improved rapidly with the result that the great majority of the spikelets were carried through to maturity.

Field Experiments on Defoliation

During the summer of 1936, an experiment was carried out on the defoliation of oat plants grown in the field. The experiment was conducted with the variety Banner grown in rod rows sown at the rate of ½ bushel per acre. Defoliation was commenced on June 24 when the plants were in the 5- or 6-leaf stage. At this time 20 plants in each of 6 rows were labelled and 4 leaves were detached from each plant. In a second series of 20 plants per row, 4 leaves were detached at the same time, and, as further leaves emerged, each penultimate leaf was detached until the plant headed when the uppermost leaf was also removed. A third series of 20 plants in each row was left untouched to serve as control plants. The percentages of blast on these plants are recorded in Table 2.

TABLF 2.—THF EFFECT OF DEFOLIATION ON THE INCIDENCE OF BLAST IN PLANTS OF BANNER OATS GROWN IN THE FIELD IN 1936

	Number of leaves detached		
	None	4	All
	Blast %	Blast %	Blast %
Row No. 6	39.7 (77)*	49.6 (65)	56.7 (56)
Row No. 19	43.6 (71)	52.4 (73)	60.6 (61)
Row No. 36	46.7 (70)	49.0 (61)	70.3 (58)
Row No. 53	45.0 (71)	41.3 (71)	62.7 (65)
Row No. 79	42.1 (76)	47.3 (65)	58.5 (67)
Row No. 84	47.1 (82)	44.5 (65)	68.2 (56)
Mean percentage blast and number of spikelets per panicle	44.0 (74.5)	47.4 (66.6)	62.8 (60.5)

* Figures in parenthesis show average number of spikelets per panicle, i.e., fertile + blasted.

The Effect on Blast of Leaf Injury Caused by the Application of Sulphuric Acid

During the same summer a second field experiment was carried out in which partial leaf destruction was secured by spraying the plants with a dilute solution of sulphuric acid. In this experiment plants of the variety Victory were grown in a series of one-hundredth acre plots. Four plots were sprayed with an 8% (by weight) aqueous solution of sulphuric acid 3 days before the first panicles began to emerge from the sheaths. The spraying resulted in the destruction of about three-quarters of the foliage but did relatively little harm to the leaf sheaths. The plants, for the most part, headed out in a normal manner. Four other plots were selected as control plots. The percentages of blast based on a count of the blasted spikelets of 20 panicles selected at random from each plot are given in Table 3. In this experiment as well as in the above experiment on defoliation, the results obtained in the greenhouse experiments were confirmed:

the percentage of blast was definitely increased by the destruction of the leaves and, in the defoliation experiment (Table 2), the number of spikelets (fertile + blasted) per panicle was reduced.

TABLE 3.—PERCENTAGE OF BLAST IN FIELD PLOTS OF VICTORY OATS PARTIALLY DEFOLIATED BY SPRAYING WITH DILUTE SULPHURIC ACID AND IN NON-SPRAYED CONTROL PLOTS

Control plots	Plots sprayed with sulphuric acid
Blast %	Blast %
49.61	58.54
48.82	64.24
52.09	62.66
51.09	61.06
Mean 50.40	Mean 61.60

THE EFFECT ON BLAST OF LEAF INJURY CAUSED BY RUST

In view of the effects on blast of leaf injury caused by the application of a spray of sulphuric acid, it seemed possible that similar effects might be caused by a severe rust epidemic providing the rust infestation took place before the plants came into head. A field experiment was planned to determine the effect of stem rust on the incidence of blast in Banner oats. Ten plots, each comprising four 5-foot rows, were planted. At an early stage of plant growth, a severe artificially induced epidemic of stem rust was developed on every second plot while the remaining plots were dusted with sulphur to prevent rust development. At the commencement of heading, leaves and parts of the stems in the rusted plots had become severely infected with stem rust and crown rust, whereas the plants in the sulphur-dusted control plots were practically rust-free. The percentages of blasted spikelets of 20 panicles picked at random from each plot are recorded in Table 4.

The injury caused by the rust to the leaves and stems is clearly reflected in the much higher percentages of blast exhibited by the rusted plants—52% as against 23% for the control plants. Nevertheless, it would probably be erroneous to include either stem rust or crown rust among the common

TABLE 4.—THE EFFECT OF A COMBINED EPIDEMIC OF STEM RUST AND CROWN RUST ON THE AMOUNT OF BLAST IN BANNER OATS

Rusted plants		Control plants	
Plot No.	Blast	Plot No.	Blast
	%		%
1	49.1	2	26.6
3	58.1	4	29.0
5	50.9	6	21.5
7	52.4	8	18.4
9	49.8	10	20.2
Mean	52.1	Mean	23.1

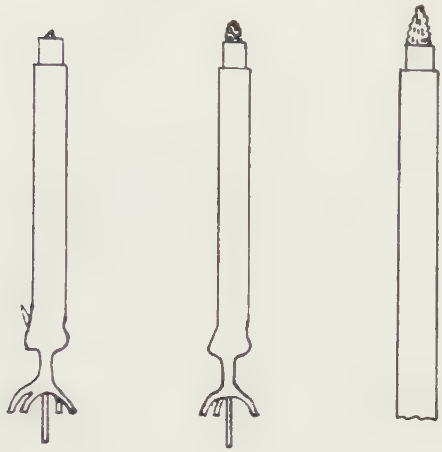

FIGURE 2. Stages of panicle development at beginning and end of first drought period. A. Average size of panicle at beginning of first drought period. B. Average size of panicle at end of first drought period. C. Average size of panicle in control plants at end of first drought period.

causes of blast in Western Canada, as these rusts rarely cause severe injury to oat plants until after the panicle has emerged, at which stage the amount of blast has already been determined.

THE EFFECT OF DROUGHT ON THE INCIDENCE OF BLAST

In recent years it has come to be realized that moisture conditions during the growing period of the oat plant bear an important relationship to the production of blasted spikelets. The work of Seelhorst (14), Elliott (4, 5), Rademacher (10) and Derick and Forsyth (3), which has been reviewed already, suggests that the amount of blast is most easily influenced during a period just prior to heading. The length of this period has, however, not been clearly defined and the investigators already referred to appear not to have kept careful records of the stages of panicle development that coincide with this critical period. It was therefore planned to subject oat plants to drought periods at two distinctly different stages of panicle development: one set of plants to an early drought period which would become effective prior to spikelet differentiation, and another set of plants to a drought which would become effective at the time of rapid panicle elongation and spikelet differentiation.

On August 1, 1936, seventy-five 6-inch pots were sown with Victory oats, each pot containing 3 plants. On September 1, when the plants had reached the 5-leaf stage, they were divided into 3 batches of 25 pots each. The plants of the first batch were kept as control plants, and received adequate watering throughout their whole growing period. The plants of the second batch were immediately subjected to a drought period of 14 days during which each pot received only 100 cc. of water every third day. At the commencement of the drought period examination of the panicles showed that the spikelet differentiation had not yet begun. Figure 2 shows the stage of panicle development at the beginning and end of this

drought period. The plants of the third batch were subjected to a similar drought period about 3 weeks later when the panicles were from $\frac{1}{4}$ to $\frac{1}{2}$ inch long. The differentiation of the spikelets was well under way, if perhaps not entirely complete, at this time.

FIGURE 3. Stage of development of panicles at the middle of the second drought period (Oct. 1). Left to right: Panicles of plants subject to early drought period; panicles of plants subject to late drought period; panicles of control plants. The two extremes of development found in each group of plants are shown.

Figure 3 shows the stages of panicle development in all three batches on October 1, when the second drought period was about half finished. After this drought period had ended, all the plants—the controls and the two drought groups—were given similar amounts of water for the remainder of their growing period. The results of this experiment are summarized in Table 5.

TABLE 5.—THE EFFECT OF DROUGHT AT DIFFERENT STAGES OF GROWTH ON PERCENTAGE OF BLAST IN VICTORY OATS

	Experiment 1		Experiment 2	
	Number spikelets per panicle	Blast	Number spikelets per panicle	Blast
		%		%
Control plants (normal watering)	53	60.1	39	38.5
Early drought period	46	50.4	32	30.6
Late drought period	56	65.9	38	65.9

Owing to the relatively small differences between the amount of blast in the control and late-drought groups of this experiment, a repetition of it was carried out under conditions of still more severe drought. The procedure employed in the second experiment differed in no way from that already described except that the amount of water supplied during the drought periods was governed solely by the amount of wilting shown by the plants. Water was supplied only when the plants showed definite signs of wilting and then only in quantities barely sufficient to permit them to recover their turgidity. At the end of the second drought period of this experiment, most of the plants were in the boot stage and a few showed signs of panicle emergence. The results of this experiment are also incorporated in Table 5.

Perhaps the most striking feature of the first experiment is the fact that the plants subjected to the early drought period showed less blast (50.4%) than the control plants (60.1%). The greatest amount of blast (65.9%) occurred in the late-drought plants. Somewhat similar results were obtained in the second experiment in which the early drought plants showed the least amount of blast, 30.6%, as against 38.5% for the control plants and 65.9% for the late drought plants.

In interpreting these results, it should be borne in mind that the late-drought period coincides with the period of active panicle elongation and floret differentiation. It is apparent that at this developmental stage the oat plant shows a greater response to drought conditions than at earlier growth stages. In both experiments, the percentage of blasted spikelets was greatest when the drought coincided with the period of most active panicle growth.

The fact that the control plants showed a higher percentage of blasted spikelets than did the early-drought plants may appear somewhat surprising. The figures for the average number of spikelets per panicle (Table 5) suggest a possible explanation. These figures show that the

effect of the early drought period was to reduce the number of spikelets per panicle. Although the control plants bore a larger number of spikelets per panicle than the early-drought plants, the number carried through to maturity in both groups was approximately the same. Consequently the percentage of blasted spikelets in the control plants was higher. It seems probable therefore that the effect of a drought at a stage of growth just prior to spikelet differentiation is to reduce the number of spikelets per panicle, which may result in lowering the yield without necessarily increasing the percentage of blast. A drought period subsequent to spikelet differentiation cannot have the effect of reducing the number of spikelets per panicle. Its effect is manifested by an increase in the proportion of blasted spikelets.

THE EFFECT OF AVAILABLE MINERAL NUTRIENTS ON THE INCIDENCE OF BLAST

As leaf injury and moisture conditions exert such a pronounced influence on the incidence of oat blast, it is not unnatural to suspect that the supply of mineral nutrients available at different stages of growth might produce a similar effect. Rademacher (11) reports an experiment in which one lot of oat plants received an abundant supply of mineral nutrients throughout the whole growing period, whereas a second lot was deprived of mineral nutrients by leaching 21 days after planting and a third lot 52 days after planting. The proportion of blasted spikelets amounted to 27% for the first lot of plants, 41% for the second lot, and 40% for the third lot. The yield in grain was approximately the same for the first and the third lot, but much lower for the second lot in which mineral nutrients were removed at an early stage of growth.

An experiment along somewhat similar lines was conducted by the authors with the object of discovering, first, to what extent mineral nutrient supply is capable of influencing the amount of blast, and, second, the stage of growth at which deficiency of mineral nutrients is most effective in exerting this influence. Plants of Victory oats were grown in 6-inch pots in the greenhouse on very poor soil—$\frac{1}{3}$ soil and $\frac{2}{3}$ sand. The plants were divided into 12 lots of 8 pots each with 4 plants in each pot. Fertilizer was applied in the form of Shive's solution (4 pts. $Ca(NO_3)_2$: 1 pt. KH_2PO_4 : 1 pt. $MgSO_4$: tr. $FeSO_4$) at various stages of plant growth, as indicated in Figure 4, and was leached out when desired by running 5 litres of water through each pot. The effect of the nutrient conditions on the number of spikelets per panicle, the percentage of blasted spikelets, and the comparative yield are also given in Figure 4. The data for yield do not represent actual yield but merely comparative yields calculated from the number of fertile spikelets produced.

Briefly, the results of this experiment show that where nutrient conditions are good shortly prior to spikelet differentiation a large panicle is formed (from 50 to 70 spikelets), while, on the other hand, where nutrient conditions are poor during this period (lots 4 to 7) the panicle is small (about 30 spikelets). Nutrient conditions in the period before spikelet differentiation, therefore, decide to a considerable extent the number of spikelets in the panicle. The figures for percentage of blast show on the other hand that nutrient conditions after the initiation of the spikelets determine the

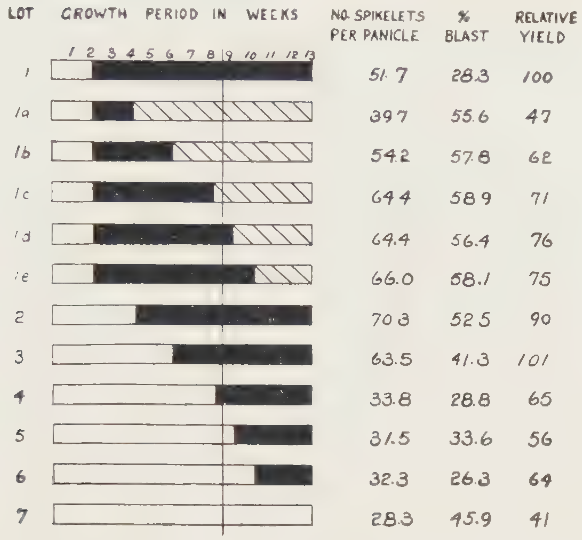

FIGURE 4. The effect of available mineral nutrients at different stages of plant growth on the incidence of blast in Victory oats. The plants were sown in very light soil ($\frac{1}{3}$ soil, $\frac{2}{3}$ sand). The white portion of each horizontal bar represents the period when no added fertilizer was present; the black portion indicates the presence of added fertilizer; the hatched portion indicates that the fertilizer was removed by leaching. The vertical line denotes the time of most rapid panicle elongation.

amount of blast. In lots 1*a*, 1*b*, 1*c*, 1*d*, and 1*e*, in which the fertilizer was leached out, the percentage of blast is highest. Where fertilizer was present until the end of the growing period it is lowest.

When yield is considered, it is obvious that, in this experiment, there is no direct relation between the percentage of blast and yield. The yield is highest where the nutrient conditions are satisfactory from sometime before panicle differentiation until the end of the growing period. Where adverse nutrient conditions set in after the differentiation of the spikelets, the yield is limited by the increased amount of blast.

RELATION BETWEEN PERCENTAGE OF BLAST AND WEIGHT PER KERNEL

Previous investigators do not appear to have considered the question of whether or not any relationship exists between the percentage of oat blast on individual panicles and the weight per oat kernel[1]. In this connection one of two possible relationships might exist. The average kernel weight might decrease with an increase in the percentate of blast, or, on the other hand, a large number of blasted spikelets on a panicle might result in a compensatory increase in the weight per kernel. In the latter event the average weight per kernel should be higher, for example, in a panicle with 70% of the spikelets blasted than in one in which only 10% of the spikelets were blasted.

In the summer of 1935 an attempt was made by means of a field experiment to determine if either of the above relationships existed. Three

[1] Since the above was written, Derick and Hamilton (Sci. Agr. 20 : 157-165. 1939) have published data giving some indication of a reduction in weight per spikelet with increased amount of blast.

oat varieties, Anthony, Banner, and Victory were planted in rod rows replicated 6 times. In each row 20 panicles were selected at random for a count of the blasted and fertile spikelets, a separate record being kept of each panicle. These panicles, when ripe, were harvested and threshed separately, and subsequently the average weight per kernel in each panicle was determined by careful weighing on a sensitive chemical balance. A considerable variation existed in the percentages of blast in different panicles of the same variety (Anthony, 3 to 54%; Banner, 21 to 62%; Victory, 22 to 84%). The average weight per kernel also varied considerably for different panicles of the same variety. An analysis of the data resulted in the following correlation coefficients for percentage of blast and average kernel weight, the paired values being in each instance taken from the same panicle: Anthony: r −0.0562, t value 0.5848; Banner: r +0.1772, t value 1.762; Victory: r −0.0399, t value 0.3929. As the t value must be at least as great as the 5% point (1.98) to show a significant correlation—which is not the case in any of the three varieties—it would seem that, in this experiment, there is no correlation between percentage of blast and kernel weight. Only in the variety Banner is there a slight indication of an increase in kernel weight with increased percentage or blast. This correlation does not, however, appear to be significant.

RATE OF SEEDING IN RELATION TO OAT BLAST

The influence of different rates of seeding on the incidence of blast does not appear to have received much attention by previous investigators. Rademacher (10), however, states that there is an optimum degree of spacing which produces a minimum of blast and that increasing closeness or wideness of seeding contributes to the severity of blast. In his opinion, the optimum degree of spacing varies somewhat according to the variety of oats sown and produces its effect on blast by its influence on the available water supply of the plants.

During the summers of 1935 and 1936 the writers conducted field experiments designed to establish what relationship, if any, exists between the rate of seeding and the incidence of blast. Four varieties were tested at 4 different rates of seeding, namely, ½, 1, 1½, and 2 bushels per acre. The varieties were sown in rod rows spaced one foot apart and replicated 6 times. The results of these experiments are summarized in Table 6.

An examination of Table 6 will show that there is a distinct tendency for the percentage of blast to decrease progressively with an increased rate of seeding. The actual losses in yield due to increased blast at the lower rates of seeding are probably not entirely commensurate with the increase in blast, as the panicle size is considerably greater at the lower seeding rates. In Banner, for example, in 1935, the blast was reduced from 43% at ½ bushel per acre to 34% at 2 bushels per acre, while at the same time the average number of spikelets (fertile + blasted) per panicle was reduced from 180 to 149. This trend is not so evident in the other varieties, although in 1935, the difference was quite noticeable in the variety Anthony.

The explanation of the greater severity of blast at the lower rates of seeding is probably to be found in the more favourable conditions sur-

rounding the early growth of the plants. In these plants many more spikelet initials are laid down than can be carried through to maturity under the less favourable conditions that frequently surround the later stages of growth.

TABLE 6.—THE EFFECT OF DIFFERENT RATES OF SEEDING ON THE INCIDENCE OF OAT BLAST

Year	Variety	Rate of seeding (bushels per acre)			
		½	1	1½	2
		Blast %	Blast %	Blast %	Blast %
1935	Banner	43*	38	37	34
	Anthony	35	32	26	23
	Gopher	12	15	17	18
1936	Banner	33	19	21	16
	Anthony	7	6	6	6
	Gopher	0.7	0.6	0.3	0.3
	Vanguard	7	5	5	3

* Each percentage figure is an average of counts of 20 panicles from each of six rows.

DATE OF SEEDING IN RELATION TO OAT BLAST

Investigators who have studied the effects of different dates of seeding on oat blast [Rademacher (10), Derick and Forsyth (3)] agree that early sown oats show a lower percentage of blast than late sown. However, as climatic conditions, which influence blast readily, differ from place to place and from season to season, it was thought advisable to test the effect of different dates of seeding on the incidence of blast under the climatic conditions that prevail at Winnipeg. Field experiments were carried out for a period of 6 years with the late-maturing varieties Anthony and Banner and the early-maturing variety Gopher. Certain other varieties were at times included in the test.

Four or 5 sowings were made each year, the first one as soon as the land could be prepared. Later sowings usually followed at intervals of one week. The seed was planted in rod rows spaced one foot apart and replicated from 5 to 8 times. The percentages of blast were obtained from a count of the blasted and fertile spikelets of 20 panicles selected at random from each row. During the last 3 years of these tests, records have been kept of the yield per acre for each variety. The results are summarized in Table 7.

It is clear from a consideration of the blast percentages recorded in Table 7 that different oat varieties show different trends with regard to the amounts of blast produced at the different dates of seeding. Of the 3 varieties subjected to all the tests the early variety Gopher is the only one in which the percentage of blasted spikelets increases progressively with later sowing. The behaviour of Ohio, another early variety included in the 1935 test, suggests that it reacts in the same manner as Gopher. In the late varieties Victory and Banner, the percentages of blast show no general trend that is applicable to all 6 years, but there is nevertheless a certain consistency of behaviour within each year. Thus, in 1934 and 1936, the highest percentages of blast occurred in the second sowing. In 1935 the

TABLE 7.—THE EFFECT OF DATE OF SEEDING ON PERCENTAGE OF BLAST, SIZE OF PANICLE, YIELD PER ACRE, AND WEIGHT PER BUSHEL

Variety	Date of seeding	1934					1935				1936				1937				1938				1939			
		May 7	May 15	May 28	June 4	June 11	May 14	May 21	May 28	June 6	May 8	May 15	May 22	May 29	May 10	May 17	May 25	June 1	May 5	May 12	May 19	May 26	Apr. 28	May 8	May 18	May 29
Anthony	No. spikelets per panicle	82	57	36	39	29	68	64	60	70	76	69	53	47	34	31	33	30	31	36	34	30	40	44	40	40
	Percentage blast	17	22	16	20	16	22	28	34	29	26	38	26	27	12	12	15	20	21	22	16	15	9	24	25	21
	Yield per acre in bu.														68	70	61	54	60	54	45	31	51	49	37	37
	Weight per bushel														37	39	40	34					34	34	34	34
Banner	No. spikelets per panicle	92	65	43	50	41	75	81	75	67	79	91	54	46	47	38	40	42	48	54	43	38	41	51	44	52
	Percentage blast	27	31	22	29	28	34	41	43	42	41	51	28	29	21	20	24	28	29	31	31	27	17	35	42	37
	Yield per acre in bu.														71	66	61	47	47	44	27	16	49	44	48	36
	Weight per bushel														37	40	37	28					37	36	36	30
Gopher	No. spikelets per panicle	69	43	39	27	26	39	39	38	31	47	43	35	33	27	25	23	24	20	19	20	20	22	29	28	29
	Percentage blast	4	14	20	16	25	10	7	7	20	2	9	16	21	9	11	9	14	7	9	10	11	3	7	9	21
	Yield per acre in bu.														60	62	60	48	50	40	36	21	59	49	46	43
	Weight per bushel														37	38	36	34					37	36	32	33
Vanguard	No. spikelets per panicle										80	70	44	41	41	36	37	33	23	30	30	31	34	38	40	36
	Percentage blast										21	33	22	22	13	10	12	19	13	15	14	21	5	16	23	16
	Yield per acre in bu.														71	67	64	53	62	59	41	31	64	56	45	43
	Weight per bushel														36	37	36	31					37	34	36	34
Victory	No. spikelets per panicle	91	54	43	44	36																				
	Percentage blast	33	35	21	27	29																				
Hajira × Banner	No. spikelets per panicle	85	63	39	38	35																				
	Percentage blast	17	28	16	22	19																				
Ohio	No. spikelets per panicle						37	38	34	35																
	Percentage blast						5	3	3	6																

highest percentages occurred in the third sowing and the lowest in the first sowing. In 1937 percentages were highest in the fourth sowing and lowest in the second. In all of the varieties, irrespective of the percentages of blast, there is a distinct tendency towards a decrease in the size of panicle (total number of spikelets per panicle) with progressively later sowing. The data for the last 3 years show that there is also a rather consistent decrease in yield per acre and weight per bushel from the second sowing to the last one. As this progressive decrease in the yields of the later sowings took place even when there was no parallel increase in the proportion of spikelets blasted, it is clear that the diminished yield results chiefly from causes other than blast, although in some years, as in 1937, the increased amount of blast in the later sowings may also be a contributing factor[1]. Probably the chief causes of the lower yields of late-sown oats are the diminution in panicle size and the reduction in tillering brought about by the less favourable growing conditions to which the plants are exposed in their earlier stages of growth. Late-sown oats were furthermore at a distinct disadvantage inasmuch as late sowing resulted in the plants maturing in a growing period that was considerably shorter than that of earlier sown plants.

DISCUSSION

In recent years and particularly since the publication of Rademacher's comprehensive studies (10, 11), oat blast has been generally accepted as a physiological condition dependent in its intensity on the variety of oats and its response to various interacting factors of the environment.

To arrive at any exact knowledge of the effect on blast of such factors as light, temperature, or soil moisture, it is necessary to resort to experiments conducted in the greenhouse where such factors are under adequate control. In the greenhouse experiments reported in this paper, an attempt was made to evaluate the effects of some of the various factors that make up the environment of plants growing in the field. Among the factors considered were: soil-moisture deficiency at two different stages of growth (an early stage and an advanced stage); defoliation and leaf injury, which in the field may take place from various causes such as insect injury, rust, or bacterial leaf diseases; and abundance or deficiency of available mineral nutrients at different growth stages. These studies have been supplemented by field experiments in which attempts were made to evaluate the effects on the incidence of blast of such cultural practices as dates of sowing and rates of sowing.

The experiments on the effect of drought at the two stages of plant growth confirm the conclusions of Seelhorst, Rademacher, and others, that there is a critical period in the growth of the plant during which the amount of blast may be readily influenced by conditions of moisture. The experimental results make it clear that this critical period coincides with active spikelet differentiation and panicle elongation. Deficiency of available moisture at this time results inevitably in the blasting of a large number of the more immature spikelets at the base of the panicle. Moisture deficiency prior to spikelet differentiation leads to quite different results,

[1] Since this was written, Derick and Hamilton (Sci. Agr. 20 : 157-165. 1939) have demonstrated that increase of blast is associated with decrease in yield.

bringing about firstly a decided reduction in the number of spikelets per panicle and secondly a reduction in the proportion of blasted spikelets. It appears probable that the second effect is a consequence of the first. The plants, stunted by a drought that terminated about the commencement of spikelet differentiation, laid down fewer spikelet initials than the plants that received normal watering during this stage of growth, namely, the control plants and the late-drought plants. The early-drought plants therefore had fewer spikelets to carry through to maturity and, as moisture conditions were favourable during the critical period, they were, therefore, able to produce about the same number of fertile spikelets as the control plants. As the total number of spikelet initials was reduced, the plants had consequently a lower percentage of blast.

Deficiency in available mineral nutrients during the critical period of panicle development appears to produce effects comparable to those resulting from moisture deficiency. Soil nutrient conditions in the period before panicle formation influence the size of panicle. Abundance of available mineral nutrients during this period—other conditions being satisfactory—lead to the production of a large panicle with numerous spikelets. A deficiency of mineral nutrients after spikelet initiation leads to the blasting of a considerable proportion of these spikelets.

The experiments on defoliation and leaf injury show conclusively that the amount of blast can be greatly increased by detaching or injuring leaves at the time that panicle elongation is taking place. The severe blast on such plants is evidently a response to the diminished flow of nutrients to the developing panicle. The experiment on the effect of an epidemic of stem rust and crown rust on blast leaves little doubt that rust injury may be a contributing factor to blast if rust develops prior to or during panicle formation. The same reasoning applies to any other leaf injuries, such as those caused by leaf spotting fungi and bacteria, or by grasshoppers. It is probable, however, that under Western Canadian conditions rust and grasshopper injuries occur usually too late in the season to have any appreciable influence on the amount of blast.

The results of the field experiments on different rates of seeding, in which there was a progressive decrease in the percentage of blast as the rate of seeding increased, would appear to be interpretable in the light of the above conclusions. It appears to be characteristic of many varieties to initiate an excessively large number of spikelets when the environment is favourable to the earlier stages of growth. The plants of the lowest rates of seeding grow more vigorously and develop larger panicles than the more closely spaced plants of the higher seeding rates. When conditions at later stages of growth become less favourable, which happens frequently, these large-panicled plants respond by blasting a considerable number of the youngest spikelets, and the more numerous the spikelets on the panicle the greater is the proportion of them thus destroyed.

Progressively later dates of seeding do not, under the climatic conditions prevailing at Winnipeg, necessarily lead to an increased percentage of blasted spikelets. The tests, carried out over a period of 6 years, did not show any consistent relationship between date of seeding and percentage of blast, except in the early varieties Gopher and Ohio in which the amount of blast progressively increased in the later sowings. In the

late varieties tested the highest percentages occurred in 1934 in the second sowing, in 1935 in the third sowing, in 1936 in the second sowing and in 1937 in the fourth (last) sowing. There was, however, a rather consistent decrease in the size of panicle from the first to the last sowing and, as shown by the yield data for the 3-year period 1937–1939, there was a progressive decrease in yield per acre from the second to the last sowing.

It appears to the authors that the experimental results here reported, and those of other investigators whose work has been summarized elsewhere in this paper, indicate clearly that oat blast is largely the consequence of a disturbance of the normal physiological equilibrium of the oat plant during the period of panicle formation. The oat plant in its development inevitably arrives at the time when it has to differentiate its spikelets and florets. The number of spikelets laid down depends upon previous developmental conditions. If these have been very favourable, the plant will lay down a large number of spikelet initials, perhaps 100 or more; if unfavourable, it will lay down a smaller number, perhaps only 25 or less. Whether or not these spikelet initials can be carried to maturity depends on the developmental conditions that follow. In general, the spikelets are developed in order from the top of the panicle to the base, the upper ones being the oldest, the basal ones the youngest. If an insufficient nutrient supply is translocated, the most advanced spikelets secure the bulk of it while the youngest spikelets on the basal branches are practically reduced to starvation. The ability to inhibit the growth of the younger spikelets is probably advantageous to the plant under circumstances in which it has produced a greater number of spikelet initials than can be carried through to maturity. It follows, therefore, that a variety of oats should not be too much discriminated against because it frequently bears a considerable number of blasted spikelets. Some of our best yielding varieties, such as Banner and Victory, are particularly subject to blast. It is characteristic of these varieties to produce very large panicles which cannot always be carried to full development. Even with a considerable amount of blast, they usually out-yield various other small-panicled varieties which show less blast.

Although this view of oat blast seems to minimize its practical importance, blast is nevertheless important, as yields may be materially reduced by it. In so far as possible an endeavour should be made to avoid the conditions favouring the development of blast. The question is how this can be done in practice. It should be stated in this connection that the oat plant develops best at relatively low temperatures. In the Prairie Provinces, oats are often sown late and, although conditions of growth are usually favourable in the early stages of growth, this crop is often subjected to hot, dry weather at the critical period for blast. Field experiments carried out for several years have shown that yields of early sown oats are very much greater than of late sown. This fact is partly accounted for in certain seasons by the increased amount of blast in the later sowings but is mainly attributable to more vigorouous plant growth of the earlier sowings. Early sowing appears to be one of the most important of agricultural practices from the point of view of yield. Another agricultural practice that appears to have some bearing on the amount of blast is rate of sowing. Field experiments have shown that there is a gradual diminution

in the amount of blast from a sowing of $\frac{1}{2}$ bushel per acre to 2 bushels per acre. The explanation is perhaps that in the thinner sowings the plants are larger and more succulent and less capable of withstanding adverse conditions in the later stages of growth. This suggestion fits in with the statement of Zade (15) that light-strawed oats with low moisture demands are less prone to the development of blasted spikelets than oats with heavier straw and greater moisture requirements.

SUMMARY

It has been shown experimentally that the amount of oat blast is readily influenced by the nutritional conditions of the oat plant from the time the spikelets are initiated until just prior to the emergence of the panicle. Any adverse influence on the normal nutritional conditions of the plant during this period tends to increase the amount of blast. At this stage of growth, the amount of blast has been experimentally increased by (1) reducing the water supply, (2) withholding mineral nutrients, (3) artificially injuring the leaves, (4) leaf injury caused by rust, and (5) growing oat plants under progressively diminishing day-length.

Field experiments on the influence of date of sowing on the incidence of blast for the 6-year period 1934–1939, show that in some oat varieties there is a tendency for early-sown oats (sown early in May) to have a lower percentage of blasted spikelets than oats sown later. Yield data for a 3-year period show that the yield per acre is highest for the earliest date of sowing and decreases progressively as oats are sown later. The decrease in yield is accompanied by a diminution in the size of the panicle and frequently, though not invariably, by an increase in the percentage of blasted spikelets. The decrease in yield appears to be largely a consequence of diminished vigour of plant growth, although the higher proportion of blasted spikelets is perhaps also a contributing factor.

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